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GENETIC PSYCHOLOGY MONOGRAPHS

Child Behavior, Animal Behavior, and Comparative Psychology

THE ACQUISITION AND INTERFERENCE OF MOTOR HABITS IN YOUNG CHILDREN*†

From the Institute of Child Welfare, University of Minnesota

By

ESTHER McGINNIS

L. C.

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY, IN THE FACULTY OF PHILOSOPHY, UNIVERSITY OF MINNESOTA

*Received by John E. Anderson of the Editorial Board, May 6, 1929.

†A study of motor learning, using two types of stylus mazes.

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To Miss Bertha Lyon and Miss Blanche Redman, Kindergarten and Nursery School teachers at the Northeast Neighborhood House, thanks are expressed for permission to carry out the experiments with children from their schools and for their personal interest in the project.

The experiment has profited by many helpful suggestions given by Dr. Florence L. Goodenough, Professor J. G. Rockwell, Dr. W. S. Miller, and Dr. J. E. Anderson, of the University of Minnesota.

My indebtedness to my brother, J. M. McGinnis, who constructed a maze suitable for such young children, who criticized and helped determine the procedure and patterns used in the second part of the experiment, and whose interest has been an inspiration throughout, is very great. ESTHER MCGINNIS

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I

INTRODUCTION

Purpose of the Experiments. In the field of learning, investigations on the ability of young children offer the most promising opportunities for real contributions to the many unsolved problems. Very few such investigations have been reported, notwithstanding the fact that the little child makes prodigious progress in all sorts of activities. Since the methods by which he learns undoubtedly condition and foreshadow the later learning, genetic studies of learning ought to be helpful in solving some of the perplexing problems.

Although many experiments have been reported on animal maze learning the results of which have frequently been applied to both the practical and fundamental problems of human learning, it seems that more would be gained from actual studies with young children (29). This investigation was undertaken, then, to compare the ability of three-, four-, and five-year-old children to learn patterns on two kinds of stylus mazes, to study the general form of the learning curve obtained, and to determine if possible the processes involved in maze learning by children.

A more specific aspect of the maze learning problem was also attacked in an experiment on transfer and interference in which a series of maze patterns and paired groups of children were used. The reliability of the mazes, age and sex differences, the relation of the abil-

ity to learn a maze to intelligence, the effect of intervals of no practice, and an analysis of errors are also investigated.

Historical Background. Studies of the physical growth of children by physicians and school officials and interest in sensory tests which developed in psychological laboratories have both contributed to the development of experimentation with the motor abilities of children. In the field of physical growth, measurements of height, weight, and strength of grip, which were at first used as measurements of motor ability, soon led to the question of the relation of these characteristics to mental ability as measured by teachers' estimates or the age-grade status of the pupil. From the psychological laboratories came the techniques and apparatus for measuring motor characteristics such as reaction-time, tapping, strength of grip, steadiness, finger reach, and tracing.

Bird T. Baldwin (5) has published a comprehensive bibliography of growth studies, including the European literature. Roberts (81) gives a selected bibliography of the main studies in this country. The field of sensory tests which grew out of the application of the methods of structural psychology to individual differences also has a voluminous literature.

Table 1 gives a chronological summary of the literature on the motor development of children, with the year of publication, number of children used, age range, locality, tests of motor ability, criteria of mental ability, the relation of the two, sex differences, and comments for each study.

The first study on motor ability alone was made by Bryan (15) in 1892 on children from 6 to 16. He used rapidity of tapping, ability to draw a straight line from one point to another, inserting a stylus in a hole, as tests or measures of motor ability, and concluded that motor ability increased with age, that growth was more pronounced in rapidity than in accuracy, that the maximum rate of voluntary movement was probably a critical test of voluntary control and furnished a test of the general condition of the nervous system.

The first experimenters to use more exact statistical methods to determine the reliability of motor tests and the mathematical relation between mental and motor abilities were Burt (17), Burt and Moore (18), and Abelson (1) in England. They applied Spearman's formulae for reliability and relationship.

In 1920 Buyse (19) summarized the literature on motor ability and classified the tests which had been used.

Oseretsky (67) in 1925 formulated a motor metric scale with six tests at each age level following the Binet plan, which he standardized on about 100 children with an age range of 4 to 15. From this he calculated the retardation or acceleration in motor development.

The literature shows unanimous agreement that motor ability in children increases with age and that it is related to the physical growth of the child. The evidence regarding the relation of motor ability to intellectual status is not so clear and many conflicting results are cited. One reason for this is the varied criteria of mental and motor ability which have been used.

TABLE 1

Chronological Outline of Motor Studies of Children

A few early studies on growth are included. The Arabic numerals after the name of the author refer to the bibliography. The following abbreviations are used: Ht., height; Wt., weight; Phys., physical; Am., American; No., number; Diff., difference; Meas., measurements; Ch., children; F.M., feebleminded; S.B., Stanford-Binet.

Year Author	No. of children	Age range in years	Locality	Tests of motor ability	Criteria of mental ability	Relation between the two	Sex differences	Comments
1872—Bowditch (81)	25	Consecutive measurements for 25 years	Boston	Ht., Wt., Phys. Meas.				
1879—Bowditch (12)	24,231	5-20					Growth curve	1st Ht., Wt., tables for Am. Ch.
1881—Peckham (70)	9,903	4-18	Milwaukee	Ht., Wt.				Confirmed Bowditch
1892—Porter (76)	33,500	6-16	St. Louis	Ht., Wt., Head Meas., vital capacity, squeeze	Classroom records Age-grade	Positive	Boys excell in vital capacity and grip	
1892—Bryan (15)	739	6-16	Worcester	Tapping, tracing, dynamometer			Boys slightly superior	Increased with age
1894—Hancock (46)	160	5-7	Worcester	Steadiness, ataxiagraph, automatograph, tapping			Girls steadier	Increased with age
1894—Gilbert (35)	1200	6-17	New Haven	Tapping, reaction-time. Phys. Meas.	Teachers' estimates	No correlation	Boys excell	Reaction-time highest correlation
1896—West (95)	15,091	5½-16	Toronto	Ht., Wt., finger reach	Teachers' estimates	No correlation		Contrary to Porter
1897—Gilbert (36)	1200	6-17	Iowa	same as previous study				
1897—Binet and Vaschide (9)	4-42	12	Paris	Tapping, reaction time dots, dynamometer, etc.	Class standing	Low correlations		Greater yith younger children Confirms Gilbert

TABLE 1 (*Cont.*)

Year Author	No. of children	Age range in years	Locality	Tests of motor ability	Criteria of mental ability	Relation between the two	Sex differences	Comments
1899—Wylie (103)	335 F. M. 95 F. M.	1-30	Minnesota	Ht. Wt. Repeated Gilbert's tests	Grade of f. m.	Positive	Boys excelled in steadiness	Below normal Ch. were deficient in motor ability according to degree of F. M. Stimulated Goddard's report
1900— (104)								
1900—Kirkpatrick (57)	500	6-17	Mass.	Vertical marks counting, sorting cards	Teachers' estimates	Positive		
1901—Bagley (4)	160	8-17	Madison	Ht., Wt., dynamometer, target, tracing, steadiness, tapping, automatograph, reaction time, card sorting, ratings on motor ability—5 groups	School marks, age-grade, teachers' ratings, no relation between reaction-time and class standing	Inverse	Boys excell	Increase with age. Wt. and motor ability have no relation
1903—Bolton (11)	111	1-5 grades	Nebraska	Tapping, tracing, steadiness, ataxiagraph	Best ward and poorest ward in the city	Positive	Girls excell	Increases with age
1903—Kelly (55)	62	9-19	Chicago	Sorting heads, sorting forms, sorting cards	Univ. of Chicago School, and a school for backward children	Positive		Increases with degree of intelligence
1906—Terman (89)	14	10-13	Worcester	Cup and ball, running downstairs, steadiness, arrow, and trough	7 brightest and 7 most stupid from 500 boys	Inverse		Bright Ch. superior in mental tests, inferior in motor tests

TABLE 1 (*Cont.*)

Year Author	No. of children	Age range in years	Locality	Tests of motor ability	Criteria of mental ability	Relation between the two	Sex differences	Comments
1906—Gesell (33)	4260	1-9 grades	Worcester	Handwriting, drawing, sewing	Class marks, judgment of teachers	Positive	Girls more accurate and coordinated	
1909—Burt (17)	43	12	England	Tapping, dealing cards, card sorting, alphabet finding	Teachers' estimates	Tapping +.41+.47 Card sorting +.50+.61		Motor tests give higher correlation than sensory tests
1911—Burt and Moore (18)	130	12½-13½	England	Tapping, fatigue, reaction-time, card dealing	Teachers' estimates, tests	Tapping +.45 Card dealing, +.36	Boys quicker in tapping and puzzles	
1911—Abelson (1)	131	Av. 11	England	Tapping, crossing out	Memory pictures, geometrical figures, as in Alpha 1	+.04 to +.43		A common factor in both
1911—Winch (98)	76	7	England	Drawing with and without tracing outline in air				Advantage is for tracing
1912—Goddard (40)	10,844	6-30 yrs.	19 institutions for F. M. in Am.	Ht. and Wt.	3 groups, moron, imbecile, and idiot	Positive		Stimulated by Porter's and Wylie's reports
1912—Glenn (37)	38	grades 6, 7, 8	Mass.	Tapping, star, Wells, peg, paper folding, tracing, sewing, manual training, etc.	Myer mental, Pintner non-language, teachers' estimates, Stanford-Binet.	Academic subjects and motor tests negative		Abilities are grouped
1914—Baldwin (5)	1924	6-18	Chicago and N. Y.	Ht., Wt., lung capacity	School marks	Positive		Tall, heavy children farthest advanced

TABLE 1 (*Cont.*)

Year Author	No. of children	Age range in years	Locality	Tests of motor ability	Criteria of mental ability	Relation between the two	Sex differences	Comments
1914—Woolley (100)	700	14-15	Cincinnati	Ht., Wt., grip, lung capacity, steadiness, tapping, card sorting	Memory association tests	+.21 at 14 yrs. +.15 at 15 yrs.		
1916—Arnold (3)	1200	9-14	New York City	Porter's tests	School progress	Positive		Confirmed Porter
1916—Johnson, B. (51)	5-48	4-10	Johns Hopkins	Tapping, steadiness, reaction time, accuracy			No large differences	
1916—Mead (62) ! !	430 F. M. 480 normal	6-26	Indiana New Jersey	Ht., Wt., grip, maze tracing	F.M. and normal	Positive		
1918—English (26)	68	12-14	England	Plunger, tapping, dotting, disc sorting, circle judging,	Social status	Children of upper class—superior except in rapidity		
1918—Pyle (80)	112	12	Missouri	Height, tapping	Age-grade	Both increase from grade to grade		
1919—Bickersteth (8)	2500	5-16	England	Tapping	Analogies	Little relation		Motor ability increases with age
1920—Buyse (19)			France	Summary of tests and literature				
1921—Perrin (71)	51	Undergraduates	Univ. of Texas	17 motor tests	Army Alpha Grades Character estimates	No correlation		

TABLE 1 (*Cont.*)

Year Author	No. of children	Age range in years	Locality	Tests of motor ability	Criteria of mental ability	Relation between the two	Sex differences	Comments
1922—Baldwin (6)	2500	5-15	Iowa	30 physical traits	Stanford-Binet	Wt. and M.A. +.71		
1922—Muscio (66)	88	13½-adults	England	10 motor tests Tapping, tracing, etc.		Low correlations between tests		There is no specific motor ability but motor abilities
1923—Garfiel (28)	32	College	Teachers College	Speed, tapping, coordination, steadiness, dynamometer	Army Alpha	+.09		
1923—Rudisill (83)	40	College		Tracing, tapping, grip, vital capacity	Army Alpha Academic grades	No relation		
1923—Gates and Taylor (30)	45	Pre-school	N.Y.City	Writing, one group copied, one traced	Group equal in mental ability			No transfer
1924—Baldwin and Stecher (7)	105	2-6	Iowa	Tracing path, Porteus, three-hole, walking board, etc.	Stanford-Binet Detroit Kindergarten	+.45 to +.79		
1924—Whitman (96)	504	7-15	Mass.	Peg boards, nuts and bolts	Myers Mental Meas.	+.65±.019	Boys excel	
1925—Oseretsky (67)	100	4-15	Germany	6 tests per yr., metric scale for motor ability				Normal Ch. in intelligence may be deficient in motor development
1925—Gesell (34)	500	Birth-6	New Haven	Writing, maze tracing, steadiness, drawing	Ability for each age level			
1925—Ruch (82)	120	School-Ch.		Card sorting, substitution, abstract	I.Q. 3 groups range of 75 points	All become more alike in card sorting		
1925—Johnson (52)	260	3-13½	New York	Tapping, target, steadiness, maze, Wt., Ht.			Girls excel in tapping	

TABLE 1 (*Cont.*)

Year Author	No. of children	Age range in years	Locality	Tests of motor ability	Criteria of mental ability	Relation between the two	Sex differences	Comments
1925—Abernethy (2)	359	6-17	Chicago	Ht., Wt., carpal area, pubescence, dentition	Otis and S.B.	Zero—carpal and M.A., zero—dentition and M.A. Wt., Ht., low		Early pubescence favors development both mentally and physically
1926—Wellman (94)	136	3-6	Iowa	Tracing board, tracing path	S.B.	No greater relation than in Phys. development	No diff.	
1926—Terman (89)	1000	2-15	California	Physical measurements, dynamometer, vital capacity	S.B.	Positive-greatest with height		
1926—Gates and Taylor (32)	82	4-6	New York	Tapping	Paired groups on M.A. and I.Q.			
1927—Cunningham (21)	100	1-3½	New York	Scale of 9 tests at each 6-mo. level	Kuhlman-Binet	+.39 +.64		
1927—Monahan and Hollingworth (64)	42	Paired with normal group	New York	Jumping, chinning, grip	Selected I.Q. above 135	Children equal in broad jump; Superior surpass in grip—below in chinning		
1928—Wilson (97)	20	8-12 Grades 3-6	California	Star tracing Witmer cylinder 16 on 3 successive days	76-148 I.Q. on Stanford-Binet	Learning curves were similar	Only boys used	

Motor ability has been tested by measuring height, weight, head measurements and body control, tapping, tracing, board and tracing path, reaction-time, finger reach, dotting, crossing out figures and letters, card sorting, target throwing, running, writing, drawing, fatigue of tapping, maze tracing, etc. Obviously, not all of these are similar and results obtained with one are not necessarily true of another. Bagley (4) long ago pointed out that to find a relationship between intelligence and weight and then to call weight motor ability was fallacious.

Again, some of the motor activities such as writing, drawing, and walking are very complex, others such as tapping are comparatively simple functions. The relation to intelligence may vary according to the degree of complexity of the responses required. Burt (17) found a closer relation between complex motor functions and intelligence than with tapping, a simple function.

Apparently the method of estimating intelligence also makes a difference in the results obtained. Porter (76), using age for grade as a criterion, found a positive relation between it and height, weight, lung capacity, and strength of grip, which has been confirmed by many others using the same criterion. When teachers' estimates of intelligence are used, exactly the opposite results are obtained, a zero relationship or an inverse one, as shown by Gilbert (35), West (95), and Bagley (4).

Related to these studies are those on various grades of feeblemindedness and on gifted children. The

feebleminded are below the average in height, weight, physical vigor, maze tracing, sorting cards, beads, etc., Wylie (103, 104), Bolton (11), Goddard (40), Kelly (55), Mead (62). The gifted are above the average in physical measurements, health, and strength of grip according to Baldwin (6), Terman (89), and Monahan and Hollingworth (64).

Another source of discrepancy is the unreliability of the measures used. Few investigators have reported the reliability. Burt (17) and Burt and Moore (18) controlled chronological age by selecting 12-year-old children, then gave each test twice, and figured the reliability of both teachers' estimates and the motor tests. The motor tests varied in reliability from +.50 for tapping to +.80 for card dealing and alphabet finding. They concluded that motor tests of a more complex nature have a greater relation to intelligence than simple tests such as tapping.

The age of the subjects is also a factor. Results with motor tests using college students and adults show low correlations with intelligence, Garfiel (28), Perrin (71), Rudisill (83). With younger children the relation is greater, as shown by Gilbert (35), Binet and Vaschide (9), Baldwin and Stecher (7), and Wellman (94).

The whole question is a complicated one and awaits further investigation by controlled scientific methods with reliable tests for both motor and mental ability.

Closely allied to these motor studies is the development of certain tests named by Wallin (92) "psycho-motor tests." By a "psycho-motor" test is meant one

TABLE 2

Chronological Table of Psycho-motor Tests

Date 1st Published	Later studies	Author	Description of test	No. of children	Age range	Reliability	Correlation with intelligence
1911		Woodworth and Wells (99)	Substitution-forms	11	Adults		
	1917	Pintner & Paterson (75)		666	4-16		
1911		Healy and Fernald (47)	23 tests—form-board, puzzles, motor co-ordination, etc.		No norms given		
	1915	Schmidt (84)	Same as above	154	5-10		
	1915	Hall, G. (44)	Healy A and 3 others	180	7-12		
	1916	Bronner (13)	Construction Test A		50% 8-yr.-olds solve it		
	1916	Bruckner and King (14)	Healy A	90 59	8 10		
	1917	Pintner and Anderson (73)	Healy Picture Completion	1500	5-16		
1912		Goddard (38, 39)	The adaptation board				
1913		Sylvester (88)	Sequin form board—devised by Sequin, used by Montessori and Whitely	1537	5-14		
	1916	Wallin (92)	Sequin form board (boys superior)	4000	2-17		
1914		Woolley and Fisher (102)	Cancellation memory for digits Substitution Completion of sentences, opposites, Healy and Fernald puzzles. Used percentile method of rating	753 680	14 15	$+.71 \pm .038$ (mental tests)	$+.21$ manual and $+.33$ mental

TABLE 2 (*cont.*)

Date 1st Published	Later studies	Author	Description of test	No. of children	Age range	Reliability	Correlation with intelligence
1914		Knox (59)	Scale for immigrants				
	1915	Pintner (72)	Knox cube	867	3-adult		
				463 F.M.			
	1917	Pintner & Paterson (75)	Used 6 of the tests of the Knox scale	664-1000	4-16		
1915		Porteus (77, 78)	Maze tests	120	3-13		
	1916	Cunningham (22)	Porteus tests and S.B.	100	4 1/2-13		+.707
	1922	Morganthau (65)	Porteus test	112	6-13	+.95	
	1924	Porteus (79)	Manual-revised	1255	6-13		
1916		Kent (56)	Geometrical puzzles	25	6-75		
			Picture puzzles	29			
1916		Young (107)	Witmer formboard (Modification of Sylvester formboard) (Boys superior)	3021	5-adults		
	1918	Ide (50)		449	5		
				311	4		
1916		Dearborn (23)	Formboards similar	70	5-adults		
	1925	Johnson (52)	to Healy B	216	5-13		
1916		Young (105)	Witmer cylinder	189	adults		
	1918	Paschal (68)	Cylinder	2053	7-adults		
	1918	Ide (50)	Cylinder	368	5		
	1922	Leaming (61)	Cylinder	600	15		
	1924	Easby-Graves (25)	Cylinder	500	6		
	1925	Jones (54)	Cylinder	120	6, 15		
				(superior)			
	1925	Paschal (69)	Witmer cylinder and 5 others	415	9, 12		
1916		Dunham (24)	Arrow formboard	184	15-18		

TABLE 2 (*cont.*)

Date 1st Published	Later studies	Author	Description of test	No. of children	Age range	Reliability	Correlation with intelligence
1917		Pintner and Paterson (74)	Adaptation board	918	4-16		
1917		Pintner and Paterson (75)	Scale of 15 performance tests	664-1000	4-16		
	1922	Johnson and Schriefer (53)	Comparison of S.B. and Pintner-Paterson	86	3-9		+.08 to +.95
1918		Wallin (93)	4 peg boards	101	9 mo.-8 yrs.		
	1924	Baldwin and Stecher (7)		59	2-6		
	1926	Stutsman (87)		150	10 mo.-3 yrs.		
	1927	Goodenough (43)		100	4	+.583	+.507 with Kuhlman-Binet
				100	3	+.688	
				100	2	+.794	
1918		Shaw (85)	Picture completion Drugstore	90	8-12		
1918		Carlisle (20)	Norms for 13 tests including Knox cube, peg board, tower	757 314 (school children)	6-13		
1920		Ferguson (27)	Series of 8 formboards	364	1st grade through college		+.50 with class standing and Army Alpha
1920		Kohs (60)	Block test				S.B. +.57 to +.82
	1925	Hutt (49)	Block test	1198	6-14		
1922		Hewes (48)	Whipple Healy tapping test	2253	7-17		

TABLE 2 (*cont.*)

Date 1st Published	Later studies	Author	Description of test	No. of children	Age range	Reliability	Correlation with intelligence
1922		Young (106)	Slot Maze A	1304	4-9		
	1924	Easby-Graves (25)	Slot Maze A	500	6		
	1925	Jones (54)	Slot Maze A	32 (superior)	6		
1923		Woolley and Cleveland (101)	Pink tower, cylinder	150	2-5		S.B.
	1923	Stutsman (87)	Performance tests for pre-school	150	1 1/2-5		+.02 +.19
1923		Sherman (86)	Fairy dot tapping	172	7-16		Zero with S.B.
1925		Johnson (52)	Compared performance and S.B.	272	3-13	+.97	S.B. +.83
1927		Goodenough (41)	Drawing a man	334	4-10	+.77	+.74 ±.016 with S.B.
1927		Hallowell (45)	3 disc form-board, peg boards, 3 figure form-board, color cubes, Witmer form-board, digits	650	1-4	Re-studied 142 cases, 73% classified in same group	
1927		Blocking (10)	Bead stringing	422			Detroit 1st grade +.532

TABLE 3

RELATED EXPERIMENTS ON PRE-SCHOOL CHILDREN

Year	Author	No. Subjects	Age range	Locality	Nature of the experiment
1921	Town (91)	52	5-6	Iowa	Analytic Study of a Group of Children—used motor tests
1923	Gates and Taylor (30)	45	5 yrs.	N.Y. City	Motor Control in Writing
1924	Baldwin and Stecher (7)	105	2-6 yrs.	Iowa City	Psychology of the Pre-school Child
1925	Gates and Taylor (31)	32		N.Y. City	Memory for Digits and Effect of Practice
1925	Gates (29)			N.Y. City	Experimental Investigations of Learning in Young Children
1925	Gesell (34)	500	B-6 yrs.	New Haven	Mental Growth of the Pre-school Child
1925	Johnson (52)	260	3-13½	N.Y. City	Comparison of Mental and Physical Development
1925	Meek (63)	71	4-6	N.Y. City	Learning and Retention in Young Children
1926	Gates and Taylor (32)	82	4-6	N.Y. City	Tapping—Effect of Practice
1926	Kirkwood (58)	203	2-6	Iowa City	Learning by Association of Forms and Pictures
1926	Wellman (94)	136	3-6	Iowa City	Motor Coordination
1926	Stutsman (87)	150	1½-3	Detroit	Performance tests
1927	Good-enough (42)	300	2-4	Minnesota	Critical Study and Evaluation of Kuhlman-Binet for Children of Pre-school Age
1927	Good-enough (43)	300	2-4	Minnesota	Wallin Peg Board Standardization
1927	Hallowell (45)	650	1-4	Philadelphia	Mental Tests for Pre-school Children
1927	Cunning-ham (21)	100	1-3½	New York	Motor Development of Infants and Young Children
1927	Burnside (16)	9 21	days to 17 mo.	Baltimore	Coordination in the Locomotion of Infants

in which there is a series of motor reactions required in the solution of a problem. It "demands motor ability to perform the appropriate muscular movements and the ability to make basic intellectual analyses and comparisons on the accuracy of which depends the ability to make the correct muscular response." Table 2 lists in chronological order some of the most important tests and the data on their standardization. The Young Slot Maze A (106) used in this experiment is such a test devised for clinical use rather than for learning.

Table 3 summarizes the related experiments on the behavior of the young child. As yet they are few in number.

Maze Learning. The maze has been widely used in animal experiments. Warden and Warner (165) in 1927 reviewed the literature and gave a chronological summary of maze experiments, citing 128 references. Miles (143) traces the history of the maze.

Table 4 lists the references in which the maze has been used for experimentation with human beings. Miles (143) classifies mazes into the following types: flat or paper mazes, a modification of the inclosure type in which people walk through the maze; the stylus maze, of which the two used in this experiment are examples; the mental maze; and the finger maze.

Reliability of the maze. The reliability of the maze as a measuring device is a greatly disputed question. In 1917, Paterson, discussing the Johns Hopkins circular maze studies, called attention to the need of a careful statistical analysis of results. He showed that

TABLE 4

CHRONOLOGICAL OUTLINE OF MAZE STUDIES USING HUMAN SUBJECTS

Date	Author	Description	Subjects No.	Subjects Age	Topic studied
1911	Whitely (167)	Paper using curved right angled and spiral patterns	9	adults	Individual differences, motor coordination and learning 20 trials each
1911	Kent (133)	Paper	18	adults	Motor coordination in dementia praecox patients
1912	Hicks and Carr (124)	Outdoor (blindfolded)	4 5	men 8-13	Comparison of learning in rats, children, and adults
1912	Boring and Day (111)	Watson circular duplicated on large scale—not blindfolded	16	adults	Introspective reports
1913	Boring (110)	Used Kent's ½ size and a pencil stylus	8	adults	Learning in dementia praecox
1914	Perrin (148)	3 pencil stylus 1 outdoor (blindfolded)	12 5	adults adults	Introspective study
1915	Porteus (77)	Paper, motor coordination, and puzzle type	120	3-13	Tests of prudence, foresight, etc.
1916	Perrin and Gould (149)	Pencil stylus—one pattern Blindfolded	10 14	11 adults	Comparison of time, errors, distance, intelligence
1917	Pechstein (146)	Pencil stylus—brass, hooded	53 59	men women	Whole and part methods of learning
1917	Webb (166)	Pencil stylus—aluminum and brass, 4 patterns, duplicate, 1 rat pattern, hooded	52	adults	Transfer and retroaction
1917	Miles (144)	Two-story indirect vision, pencil stylus, Boring (1913) pattern	70	adults	Used originally for a motor test Cox intelligence
1919	Carr (114)	Pencil stylus Webb pattern—blindfolded	20	adults	Distribution of effort
1920	Dashiell (118)	1 made of screens 2 stylus pencil		children adults	Complete versus alternate methods of learning

TABLE 4 (*Cont.*)

Date	Author	Description	Subjects No.	Subjects Age	Topic studied
1920	Dunlap (120)	Paper similar to Whitely—rt. angles with confusing lines	2	adults	Effects of alcohol on coordination
1920	Peterson (150)	Mental patterns called out by experimenter	19	adults	Backward elimination of errors
1921	Barton (108)	Stylus maze—blindfolded	34	adults	Whole versus part
1921	Carr (115)	Visual cues similar—stylus blocked underneath	64	adults	Effect of visual guidance
1922	Carr and Osborne (117)	Stylus, circular disc of aluminum attached to stylus to hide pattern	77	adults	Effect of vision
1922	Hunter (127)	Pencil stylus, 2 patterns blindfolded	73	adults	Correlation studies Reliability +.64 ±.077
1922	Hunter (129)	Pencil stylus (blindfolded)	31	adults	Habit interference
1922	Peterson (151)	Mental maze	20	adults	Frequency and recency
1922	Young (106)	Slot maze A vision permitted	1304	4-9	Clinical test (2 trials)
1923	Heron (122)	5 mazes, hood used	107	adults	Individual differences versus chance
1923	Koch (135)	Stylus—plugs to stop alleyways—hooded	150	adults	Effect of mechanical guidance
1923	Ludgate (139)	Stylus—2 patterns hooded	255	adults	Effect of manual guidance
1924	Hunter and Randolph (131)	Stylus—blindfolded	100	adults	Reliability of maze with rats and humans
1924	McQuarrie (142)	Eye mazes. Pattern traced by eye alone. Reported by Miles			Measure of mechanical ability motor control
1924	Tsai (158)	Pencil stylus—same as Heron—hooded	96	adults	Retention curves
1924	Warden (162)	Stylus-T pattern hooded	60	adults	Methods used—Primacy-recency
1925	Warden (163)	Stylus-T pattern hooded	60	adults	Space relations
1925	Gesell (34)	Paper maze	50	5	Personality
1925	McClatchy (140)	Stylus—curtained	243	adults	Distribution of learning

TABLE 4 (*Cont.*)

Date	Author	Description	Subjects No.	Subjects Age	Topic studied
1925	Wang (159)	Used Ludgate maze—hooded	315	adults	Influence of tuition
1926	Kline and Stevenson (134)	Stylus maze—Hampton Court type—screened	8	adults	Transfer and Inhibition between hands
1926	Koch and Ufkess (136)	Stylus—concealed	19 blind 20 normal	12-26 14-32	Comparison of blind and seeing
1927	Perkins (147)	Flat paper mazes. Looked at through tube. Vision of a section of the path at a time. Lighted from below.	75	adults	Human reactions in a maze of fixed orientation
1927	Smith (152)	Circular mazes—partial vision	200	adults	Insight and trial and error
1928	McGinnis (141)	Modification of Carr non-visual cue maze. Maze for children			A child's stylus maze
1928	Husband (132)	Used Miles raised finger maze blindfolded	80	adults	Human learning, comparison of raised and ordinary maze
1928	Miles (143)	Raised finger maze			Description

age and sex differences in Hubbert's (125) and Bassett's (109) work when treated statistically were not significant.

Heron (123) and Hunter (128) in 1922, Hunter and Randolph (131) in 1924, Heron (122) in 1924, Tolman (155) in 1924, Davis and Tolman (119) in 1924, and Liggett (138) in 1925 reported on reliability with varying results.

Carr (116) in 1926 replied to Hunter's interpretation of his 1924 results and pointed out that 80% of

Hunter's correlations were positive, that the maze was used for group and not individual differences, and that a crude measure may be used to distinguish differences which are of a considerable magnitude. He also emphasized the fact that successive trials on a maze are not comparable because of the practice effect, and asked what degree of correlation must be had before the maze could be used.

Hunter (130), 1926, answered by stressing the need for calibrated measures in psychology, and insisted the present correlations were too low for acceptance. He quoted Kelley that a correlation must be +.40 or more to distinguish group differences and +.90 or more for individual differences.

In this connection Tryon (157), 1926, pointed out the effect of unreliability of the measuring device on the obtained difference, and showed that the real difference would be greater than the obtained difference. The more unreliable the measuring instrument, the greater significance the obtained difference has. He presented a formula to correct for the unreliability of the measuring instrument.

Recently, in 1927, Stone and Nyswander (153) tried four methods of determining reliability using a multiple T-Maze and rats. They were: correlations of the sum of the errors on odd and even trials, the sum of errors on odd-numbered blinds with even-numbered blinds, the sum of all errors for the first half with errors for the second half, and the sum of any one segment of learning with another segment. They also used methods one and four for time scores. The ob-

tained correlations were around +.5 to +.9, with the correlations of the sum of the errors on odd and even trials giving the highest correlations. They recommended using two or three methods on the same data.

Tolman and Nyswander (156), 1927, cited the literature on reliability of maze studies and concluded the correlations reported center about +.30. For measuring individual differences this is too low, but for group differences at two extremes, it can be used. They analyzed the factors affecting the correlations, such as shape of maze, effect of experimenter in controlling conditions, and the technique used in calculating the correlations. Then they listed seven experiments on different types of mazes using runs 3 to 32 and found reliabilities, using errors on odd versus even runs, of +.44 to +.83, correlating one half with another half, +.035 to +.821. They concluded that forward going right and left and T-mazes were best and that a 14-unit T-maze was the most reliable.

In a study of family resemblance in maze learning ability, Burlingame and Stone (113), 1928, used the T-maze, the careful technique of handling the animals, and the four methods, suggested by Stone and Nyswander (153), and obtained reliability coefficients ranging from +.78 to +.937, which are the highest so far reported.

Transfer and interference experiments. Transfer in learning has been studied thoroughly with a wide variety of subjects. In the 1928 Year Book of the National Society for the Study of Education, Whipple (185) summarizes "The Transfer of Train-

ing" in school subjects. He calls attention to reviews by Thorndike, 1913, Starch, 1920, and Rugg, which cite the studies prior to 1915. In part four, Whipple concludes that, while many of the experiments were inadequate, the preponderance of evidence was for transfer. The question then becomes how transfer takes place and how much transfer there is. The three accepted doctrines are common elements, common content, and common method. When transfer impairs the second activity rather than improves it, it is called negative transfer or interference. Negative transfer is noticed most at the beginning of the second activity and may become positive if the activity continues long enough.

The first report on transfer in animal learning was mentioned incidentally in Yerkes' (170) experiments with "The Dancing Mouse," when he said the dancing mouse learned more rapidly after training on one maze than with no previous training.

In 1917 Webb (166) made an extensive investigation of transfer of training and retroaction, using six patterns with rats and four duplicates of the rat mazes with humans. In summarizing the literature he states that there had been no previous experiments on transfer in the animal field (p. 6), nor on transfer in maze activity with humans (p. 7), nor any retroaction experiments with "sensori-motor activities." He found the "acquisition of any maze activity must thus be regarded as exerting some disintegrating effect upon the maze habits previously mastered." The transfer effect was measured by the difference between "original

learning and transferred learning in terms of trials, errors, and time." He had positive transfer in every case and found that a positive correlation existed between the degree of transfer and the difficulty of the second problem. The transfer was limited to the early stages.

Practically all experimenters have found transfer in maze habits both for rats and human beings. [Wylie (169), 1919, Wiltbank (168), 1919, Hazlett (121), 1919, Brockbank (112), 1919, Barton (108), 1921, Hunter (128), 1922, Ludgate (139), 1923, Warden (162), 1924.] The interference reported has been in visual and auditory habits or in the problem box with squirrels. The transfer was positive when measured by savings in total time, errors, and trials or a comparison of the first trials of the two habits.

The subject of habit formation is an inclusive one and the literature is voluminous. This review covers briefly the literature on motor studies with children, psycho-motor tests, experiments in learning with preschool children, human maze learning, the reliability of the maze as an experimental device, and transfer and interference in maze learning.

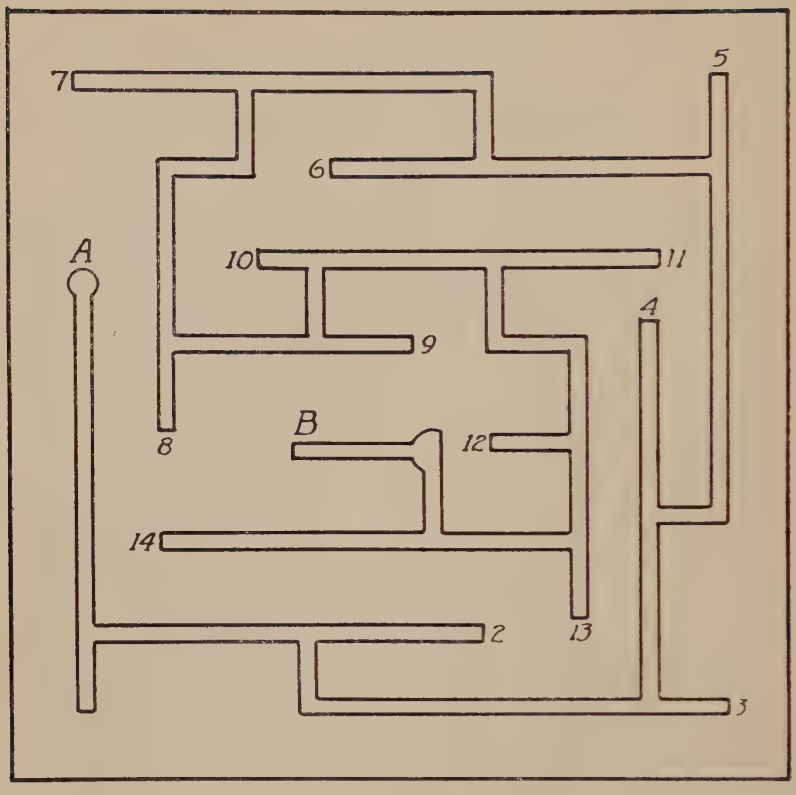
II

THE LEARNING EXPERIMENT ON THE YOUNG SLOT MAZE A

Experimental Procedure. The first part of the investigation is a comparison of the age and sex differences of young children learning the pattern of the Young Slot Maze A. This maze was designed by H. H. Young (106) of the University of Indiana as a psychometric test.

The pattern (see Figure 1) is cut out of an aluminum panel which is mounted on board in such a way "that the slot with all its blind alleys furnishes a free passage way for the movement of the slider so constructed that it cannot be removed from the board except at the ends of the course. This makes the test practically "fool proof," and eliminates the necessity for negative instructions. The maze is 12″ x 12″. The blind alleys are 3/16 of an inch wide and are continuous with the path. A toy boy clown (*b*) painted blue and black, about 1 and 1/2 inches high, is set at the end as a goal (*B*). He stands with his back to the starting point and faces the slot down which the slider will approach him. The stylus (*c*) is a round disc on which is mounted a toy shoe also colored. There are circles at the beginning *A* and at the goal *B* to permit the insertion and removal of the stylus."

Young's method is as follows: "The maze is placed in front of the child so that the right side of the goal boy is toward the child. This position of the test makes



a

b

c

FIGURE 1

YOUNG SLOT MAZE A

the slot leading from the starting-point *A* point to ward the child. The instructions to the child are: 'See this boy? (Pointing to the boy). This (grasping the shoe) is his shoe. The boy wants his shoe. I want you to take it to him. See how quickly you can take the shoe to the boy.' (With these words the shoe being firmly grasped by the examiner is slowly moved several inches along the slot directly toward the child.) The word *around* must not be used in the directions, as it would be a cue. The time is counted in seconds from the instant the above directions are completed until the child gets the shoe in the slot in front of and against the boy. If the child does not complete the test by the end of five minues his record is marked D. N. C., and the test is stopped." If the child stops he is urged, "The boy wants his shoe, take it to him," or "Go on, put the shoe in the boy's hands." No instruction should be given. Children who complete the first trial within the time limit are given a second with the instructions, "See if you can take it (pointing to the shoe) to him quicker this time." Five minutes is the limit here also.

The maze as purchased had square corners as shown in the diagram. Either because of imperfect workmanship or the squares themselves, the stylus sometimes stuck at the corners. In order to remedy this, the corners were smoothed with a file until the stylus would slide without hindrance. This probably reduced the time somewhat. Instead of calling the figure a boy, it was called a man, and the game was known by the children as the "man-and-shoe game." The directions

are the same as Young's, but time was not taken until the child actually started to move the stylus. Sometimes it was necessary to stop the stop-watch when the children who were very distractable talked or looked around the room. This might be compared to what is known as static time with rats! Also in the three-year-old group help was sometimes given around the first turn of the maze. The watch was stopped when the shoe reached the round hole instead of waiting until the shoe was against the man as many of the children stopped there or slowed up and began to talk. Young (106) says nothing about errors, but in these experiments the blind alleys were numbered in pencil very lightly so as not to be noticeable (see Figure 1), and errors were recorded on the record blank by number.

Experimental Results

Composition of groups. In order to compare learning ability, twenty children at each of three age levels were used. The sexes were evenly divided and the average age of each group was three, four, and five years. The children in the nursery school of the Institute of Child Welfare at the University of Minnesota were used first. Then the groups were filled with children from the nursery school and kindergarten of the Northeast Neighborhood House in Minneapolis.

Table 5 shows the average chronological age, mental age, and I.Q. for the entire group as well as for boys and girls separately.

The greatest discrepancies are found in Group II where the girls are three months younger than the boys,

TABLE 5
COMPOSITION OF GROUPS

No. of the group	No. of children		C.A. in mos. Mean	C.A. in mos. S.D.	M.A. in mos. Mean	M.A. in mos. S.D.	I.Q. Mean	I.Q. S.D.
I	Boys	10	59.7	3.5	61.7	6.6	103.5	11.6
	Girls	10	59.5	3.2	66.7	11.3	112.4	20.5
	Total	20	59.6	3.4	64.2	8.9	107.9	17.5
II	Boys	10	48.2	2.9	56.3	6.3	116.8	10.5
	Girls	10	45.4	3.3	53.7	7.1	118.2	15.2
	Total	20	46.8	3.1	55.0	6.9	117.5	13.4
III	Boys	10	36.5	4.0	38.7	8.3	105.3	14.4
	Girls	10	37.1	3.5	39.8	8.0	102.2	12.2
	Total	20	36.8	3.8	39.3	8.2	103.8	13.5

and in the average I.Q. of Group II which, while similar for boys and girls, is 10 points above Group I and 13.7 above Group III. The I.Q.'s were obtained on two scales, the Kuhlman-Binet and the Minnesota Pre-school Scale.

Time intervals. The experiments began in October, 1927, and continued through March, 1928. Five consecutive trials a day, five days a week (omitting Saturday and Sunday), for two weeks made a total of 50 trials for each child or 3000 trials for the group of 60 children. The time intervals then were 24 hours between each five trials and 72 hours between the 25th and 26th trials, from Friday to Monday. The irregular attendance of pre-school children due to colds, infections, the weather, and holidays is a serious handicap in any experiment which requires the children every day for two weeks.

There were 28 children (46 2/3%) who carried out the experiment as planned, 11 in Group II, 10 in Group III, and only 7 in Group I, the oldest group. The largest number of children, 6, who were absent three or

more days, however, was in Group III, the youngest group, with a total of 29 days. There were no marked differences between the boys and girls and no constant differences between groups. The total of 98 days of absence, however, does clearly show one of the difficulties in trying to do controlled experimentation with pre-school children.

Motivation. Several methods were used to obtain a maximum degree of effort. First, the maze itself was attractive to the children with its gayly colored man and toy shoe. The name "man-and-shoe game" also appealed to them.

Secondly, the trials were timed with a stop-watch and this was used as an incentive. The child often asked, "How fast did I go that time?" He was told in an enthusiastic way, "You did fine that time," "That was a dandy one," or "That wasn't quite so good but this time I'm sure you can go faster." The older children often kept track of the trials and would say, "Two more now," or "This is the fourth, isn't it?" or the examiner would say, "Now this is the last one, let's see if you can't beat your record today." Urging was not done after the child had started a trial and talking then was discouraged.

Thirdly, as a reward at the end of the five trials, the examiner took the man out of the maze, drew an outline of it and a picture of the shoe on a slip of colored paper which was given to the child. The examiner talked as she drew. "Here's his funny hat, that's his collar, those are the buttons on the shoe, etc." The colors of the paper were changed frequently and often

the child asked for two men, or a big shoe and a baby shoe, etc. These requests were always carried out if possible. (Figure 1*b, c.*)

While there are no objective measures of the success of the motivation, it is significant that a number of the children who continued on the second part of this experiment continued to ask for "man-and-shoe pictures" as a reward, and the children who did the experiment the first year would, even the following winter, ask if they could come in and play and have a picture of the man and shoe. The pictures were frequently taken home and usually shown to other children, etc. The consensus of opinion of the adults around the nursery school was that for some reason or other it seemed to make a genuine and lasting appeal to the child. Perhaps it was the fact that the picture was drawn while he looked on and the comments were similar to the repetitive stories which children of this age like so much. The human interest of the "man" and his need for his shoe, the colored papers, and the picture to keep probably all helped.

Reliability. The coefficients of reliability reported for maze learning are usually around +.3 or +.4 for animals and as high as +.6 for adults (Hunter, 127). The reliability varies with the pattern used (Heron, 122) and with the technique of handling the experiment (Tolman and Nyswander, 156).

It is particularly interesting then to note the results obtained with such young children. Reliability may be measured in various ways. Time or errors may be used, odd versus even trials, first half versus second half,

different segments of learning with each other. Tolman (155) reported that the correlation of time on odd versus even trials gave the highest coefficients in his experiment. In this experiment the Pearson product-moment method of correlation of time on odd versus even trials, with trials 5-50, was used. Trials 5-50 were selected because many investigators have noted the unreliability of the first few trials and have recommended omitting them in the calculations. Any of the methods mentioned above are affected by the fact that from one trial to the next in a learning problem the individual has progressed on the learning curve, which means that the two trials cannot be considered comparable.

TABLE 6

RELIABILITY COEFFICIENTS OF CRUDE TIME SCORES, TRIALS 5-50, ODD VERSUS EVEN

Group	No. of children	No. of trials	r	S.E.
I	20	920	.619	±.014
II	20	920	.646	±.013
III	20	920	.605	±.014
Three Groups	60	2760	.618	±.017

The reliability for the total group of 60 children on trials 5-50 was +.618±.017, S.E. If 2710 trials were used, omitting 50 very erratic ones, the correlation is +.738±.012, S.E. This is probably not a legitimate procedure, however. The +.618 corresponds closely to Hunter's reliability for adults and is higher than experiments reported for rats. It seems that it is justifiable to use this maze to study group differences as Kelley (130) has stated that measuring instruments whose reliability is above +.4 may be used for group differ-

ences but will not differentiate individuals. The coefficients for the groups separately were also +.6.

Stone and Nyswander (153) and Burlingame and Stone (113) have recently recommended four methods for determining the reliability of maze experiments. They used the sums of errors on odd and even trials, the sums of errors on odd and even blinds, the sums of errors on first half with second half, and the sums of errors on different segments of learning. The highest correlations so far reported were obtained with a

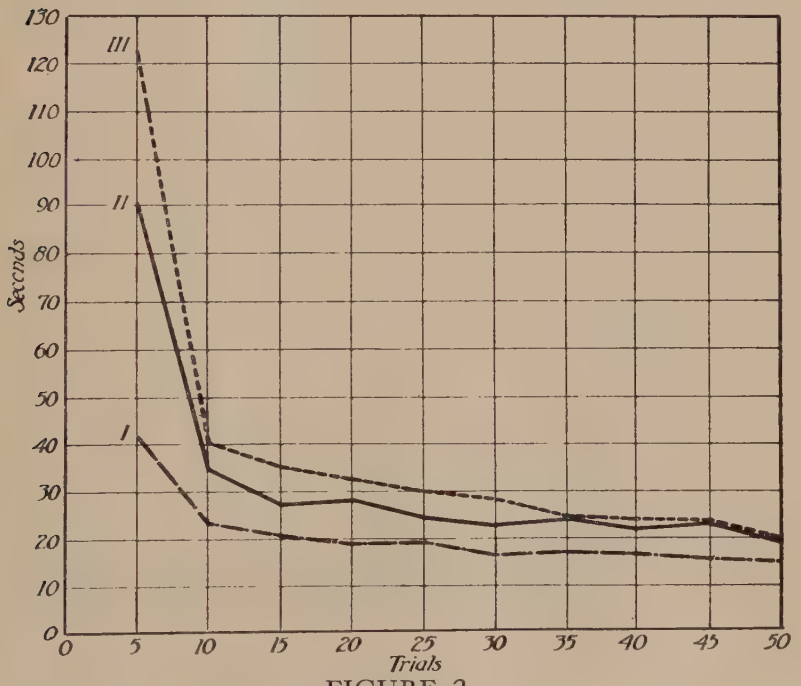


FIGURE 2

AGE DIFFERENCES IN TIME SCORES

Group I—age five years, Group II—age four years, Group III—age three years

range of +.7 to +.9. This procedure can be defended only when the maze is looked upon as a test where the different parts of the test are given over a longer time interval, a few trials every day. It does not give reliability for an individual or a group at any definite point in the learning process, which is usually the purpose for which the maze is used. The maze, however, might be looked upon as such a test, so correlations for the sums of time on odd and even trials and sums of errors on odd and even trials were computed. The correlations correspond very closely to those reported by Stone and Nyswander, +.8 and +.9. Looked

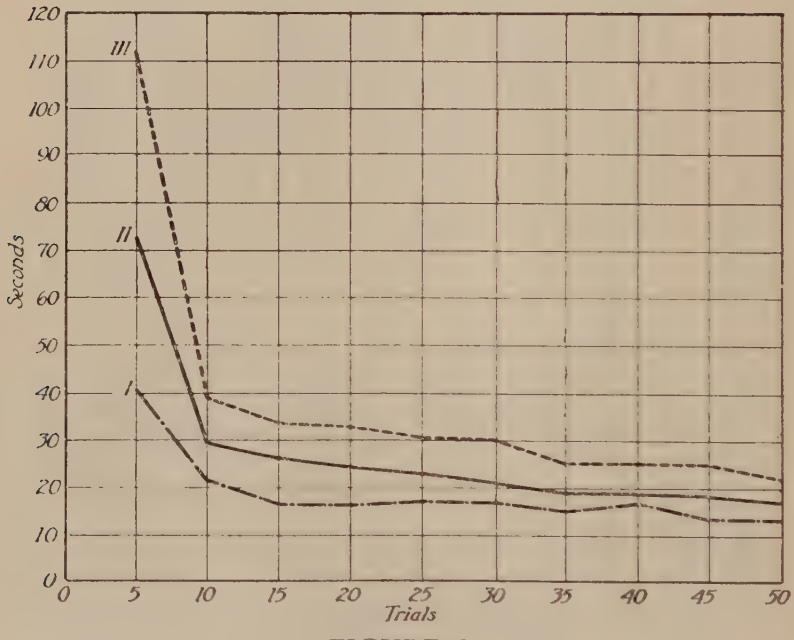


FIGURE 3

Boys

TABLE 7

CORRELATIONS OF SUMS OF ODD AND EVEN TRIALS

Group	Time in seconds	S.E.	Errors	S.E.
I	+.876	±.052	+.81	±.07
II	+.829	±.069	+.91	±.04
III	+.928	±.031	+.98	±.009

at in this way, the maze has as high reliability as most tests. But it should be emphasized again that this method cannot be used for reliability in determining

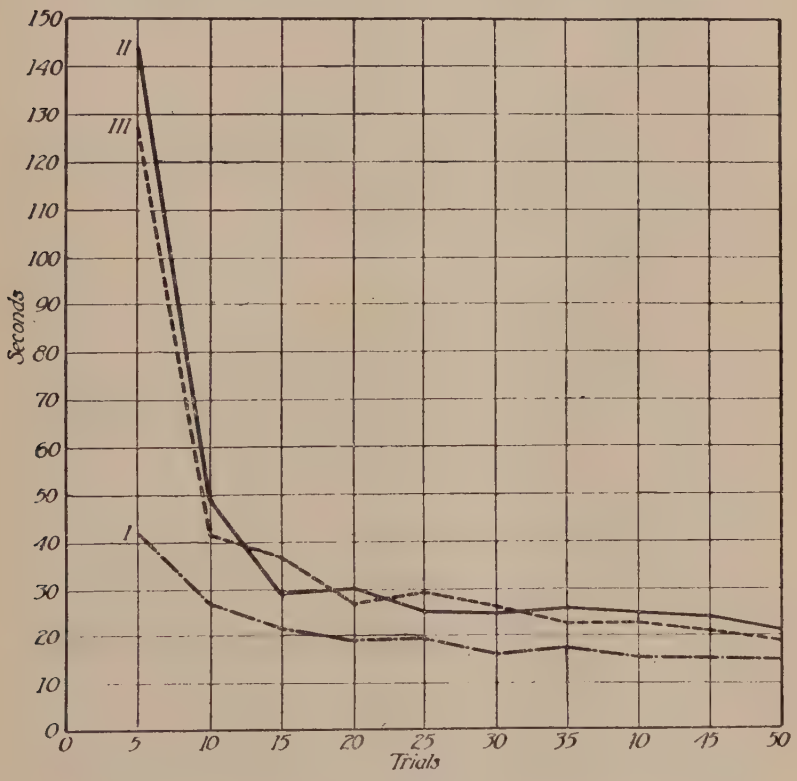


FIGURE 4

GIRLS

the status of the individual or group in a learning process.

Analysis of age differences. Figures 2 and 5 give the time and error curves for the three age groups obtained by plotting the medians of every five trials. The age differences stand out clearly except that the curves

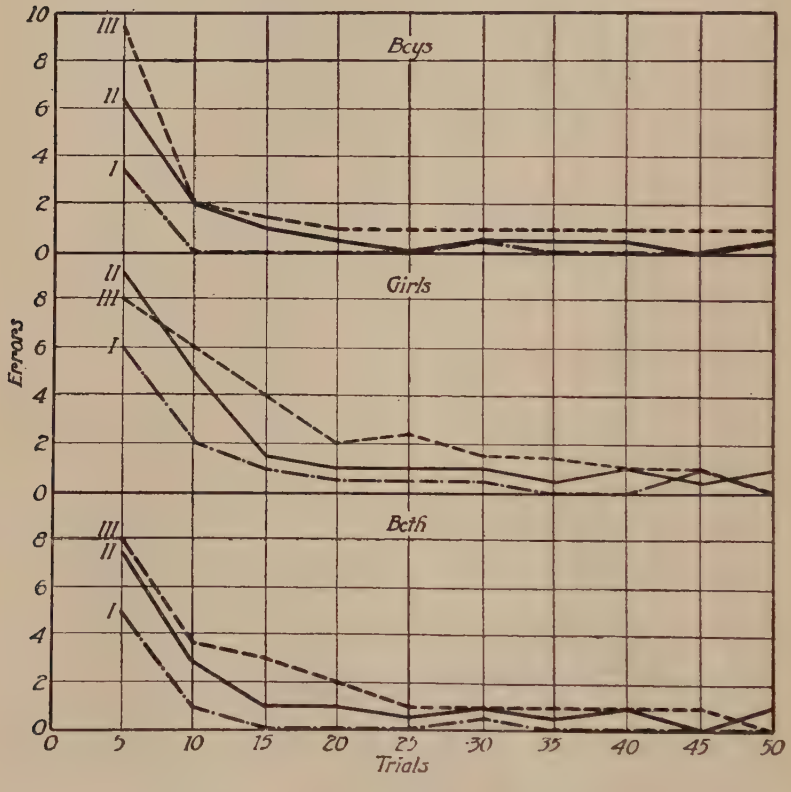


FIGURE 5

AGE DIFFERENCES IN ERROR SCORES

Group I—age five years, Group II—age four years, Group III—age three years

for Groups II and III approach each other from the 35th trial on. One factor may be that there is, on the average, only eight months' difference between the girls of Groups II and III instead of a year.

TABLE 8

MEDIANS OF FIVE TRIALS IN SECONDS

Group	Trials 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50
I	42.4	23.3	20.3	18.5	18.7	16.1	16.5	16.1	15.1	14.7
II	90.2	34.7	27.3	27.8	24.3	22.5	23.6	21.5	22.0	18.5
III	122.9	40.4	35.0	32.0	29.9	27.9	24.1	23.7	22.7	19.4

TABLE 9

ERROR MEDIANS BY FIVE TRIALS

Group	Trials 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50
I	5.0	1.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
II	7.5	3.0	1.0	1.0	0.5	1.0	0.5	1.0	0.0	1.0
III	8.0	3.5	3.0	2.0	1.5	1.0	1.0	1.0	1.0	0.0

The error curves are shown in the bottom graph on Figure 5. Because the pattern is very simple the level of performance is reached at about the 25th trial and from then on the curves flatten out although age differences on the whole remain.

Table 10 gives the group averages in seconds for the initial, best, and final trials with the standard error of the differences between groups for the initial and best trials.

Again the differences between Groups I and II are marked in the initial trial, less in the best trial, but even here are statistically reliable. Groups II and III tend to overlap even when the children in Group III, who were unable to learn the maze, are included in the ini-

TABLE 10

GROUP AVERAGES OF INITIAL, BEST, AND FINAL TRIALS IN SECONDS

Group	No. of ch.	Initial trial Total	S.D.	Mean	S.E.	Best trial Total	S.D.	Mean	S.E.	Final trial Total	Mean
I	20	2584.5	85.7	129.2	19.2	223.1	3.1	11.2	.69	317.6	15.8
II	20	4067.4	98.5	203.4	22.0	262.6	3.1	13.1	.68	368.0	18.4
III	20	4292.4	85.3	214.6	19.1	298.0	3.9	14.9	.88	360.2	18.0
III	27	6392.4	86.1	236.8	16.6						

	Actual diff.	S.E. diff.	diff. / S.E.	Actual diff.	S.E. diff.	diff. / S.E.
I & II	74.2	29.1	2.5	1.9	.97	1.96
II & III	33.4	27.6	1.2	1.8	1.1	1.63
I & III	107.6	25.9	4.2	3.7	1.1	3.36

tial trial. In order to obtain 20 children in Group III, 27 were tried. Seven, one boy and six girls, were unable to do it. Their records have been included only under the initial trial and have not been used in plotting the graphs. If they were included, Group III median for both boys and girls would be 300 seconds and the initial inversion would disappear. Of course, there is no record of further trials for these children so the curves can show only the actual group of 20.

TABLE 11

TOTAL TIME AND ERRORS BY GROUPS

Group	No. of ch.	Time in seconds Total	Mean	S.E.	Errors Total	Mean	S.E.
I	20	24,227.2	1211.4	38.8	1572.0	78.6	16.4
II	20	39,085.4	1954.3	51.8	2178.0	108.9	10.5
III	20	41,423.2	2071.2	68.7	3074.0	153.7	19.7

	Actual diff.	S.E. diff.	Ratio	Actual diff.	S.E. diff.	Ratio
I & II	742.9	64.7	11.5	30.3	19.5	1.6
II & III	116.9	86.0	1.4	44.8	22.3	2.0
I & III	859.8	79.9	10.8	75.1	25.6	2.9

However, the highly selected nature of the girls in Group III undoubtedly influenced the overlapping of the curves and averages in Groups II and III.

The total time decreases with age as do errors. The differences between Groups I and II are again greater than between II and III in time, but in errors the differences increase regularly with age.

Figures 3, 4, and 5 show the age differences for boys and girls separately in both time and errors. The girls of Groups II and III overlap somewhat in both the time and error curves. The boys in Groups I, II, and III remain clearly separated on the time curves with some overlapping on errors towards the end of learning period. This was probably due to the fact that the errors were eliminated early by all groups and the maze was too easy to differentiate ages by errors.

The data, on the whole, confirm the work of other investigators that motor ability increases with age, whether time or errors are used as the criterion of learning.

Sex differences. Young (106), in his report of the standardization of the Slot Maze A ("man-and-shoe maze") as a test, found marked sex differences, the boys exceeding the girls on the average by about a year at four years and two years at the age of eight. He used 642 boys and 662 girls from 4-8 years. Since then, Easby-Graves (25) has also reported results using 500 six-year-old children. A comparison of the results of this experiment with Easby-Graves and Young is given in the following table.

Direct comparisons cannot be made because of the

TABLE 12

Percentage Not Completing the First Trial

		No. of children	Age 6 Yrs. %	No. of children	Age 5 Yrs. %	No. of children	Age 4 Yrs. %	No. of children	Age 3 Yrs. %
Young	Boys	168	10	126	30	39	50		
	Girls	206	40	128	50	36	60		
Easby-	Boys	256	4.6						
Graves	Girls	244	12.4						
McGinnis	Boys			10	0	10	20	11	54.5
	Girls			10	30	10	60	16	62.5

TABLE 13

Percentage of Failures on First and Second Trials

Trial	Boys		Girls	
	Young %	McGinnis %	Young %	McGinnis %
1	19.0	25.8	38.0	52.8
2	3.4	10.0	6.3	20.0

TABLE 14

Initial, Final, and Best Trials in Seconds

Group	No.	Initial trial Total	Mean	S.E.	Best trial Total	Mean	S.E.	Final Total	Mean
I									
Boys	10	934.3	93.4	±13.9	115.4	11.5	±1.21	159.8	15.9
Girls	10	1650.2	165.0	±31.4	107.7	10.7	± .75	157.8	15.8
II									
Boys	10	1741.7	174.2	±28.3	117.3	11.7	±1.11	174.7	17.5
Girls	10	2325.7	232.6	±28.1	145.3	14.5	± .72	193.3	19.3
III									
Boys	10	2062.3	206.2	±30.3	150.8	15.1	±1.25	183.7	18.4
Girls	10	2230.1	223.0	±24.5	147.2	14.7	±1.26	176.5	17.7
Boys	11	2362.3	214.4	±28.8					
Girls	16	4030.1	251.9	± 6.9					

Group	No.	Initial trial Actual diff.	S.E. diff.	Ratio	Best trial Actual diff.	S.E. diff.	Ratio
I	20	71.6	34.3	2.1	.8	1.42	.56
II	20	58.4	30.8	1.5	2.8	1.32	2.12
III	20	16.8	38.9	.4	.4	1.77	.23
III	27	37.5	33.4	1.1			

small number of children in this experiment, but the tendency of the three groups is the same as in the Young and Easby-Graves data. Our children were apparently somewhat above the average in their ability on the initial trial. The distinct sex differences in favor of the boys at each age and in all three experiments are also evident.

Young reported results for the second trial also. Table 13 gives the percentage of failures in both sets of data on trials 1 and 2.

As our group included three-year-old children and smaller numbers, the percentages of failure are higher than Young's, but the direction of the differences between the sexes in both cases is similar.

An interesting point about the sex differences is that while all the investigators agree that there are marked sex differences in the initial attack on the Young Slot Maze, when 50 trials instead of two are given, the sex differences largely disappear. That is, the factor which gave the boys a decided advantage at the beginning did not operate as learning continued. It may be that the initial attack is partly the function of a pattern-seeing ability in which apparently the boys excel (see section on Picture Mazes) and that continued improvement after the maze is learned is due to the development of skill in motor coordination. Wellman (94) found no sex differences in motor coordination. Whether this is a correct explanation or not, the fact remains that the rather large initial sex differences, found by Young, Easby-Graves, and confirmed in this experiment, tend to disappear when learning is continued for 50 trials.

TABLE 15

TIME MEDIANS IN SECONDS BY FIVE TRIALS FOR BOYS AND GIRLS

Trials		5	10	15	20	25	30	35	40	45	50
I	Boys	41.7	21.6	16.7	16.6	17.4	17.1	15.2	17.3	14.4	14.4
	Girls	42.4	26.8	21.7	19.1	19.5	16.1	17.5	15.3	15.2	14.7
II	Boys	73.2	29.6	26.3	24.2	23.2	21.3	18.7	18.8	18.0	17.4
	Girls	144.4	48.5	28.7	30.5	25.4	24.5	25.6	24.8	24.4	21.1
III	Boys	112.1	38.9	33.6	33.0	30.6	29.9	25.3	25.3	25.1	22.1
	Girls	127.7	42.0	37.0	27.2	28.7	26.1	22.6	23.1	21.3	18.1

The data seem to show, then, that although the girls start with a handicap, by the end of the learning period, they have reached practically the same level of ability as the boys. This is most clearly shown in the graphs showing the medians of time and errors for boys and girls in which there is overlapping both in time and errors for each group except II. (See Figures 6, 7, 8, 9.)

Tables 15 and 16, from which the graphs were made, give the medians by five trials for boys and girls in seconds and errors.

Goodenough (175) has recently summarized the literature on sex differences in mental traits. She found

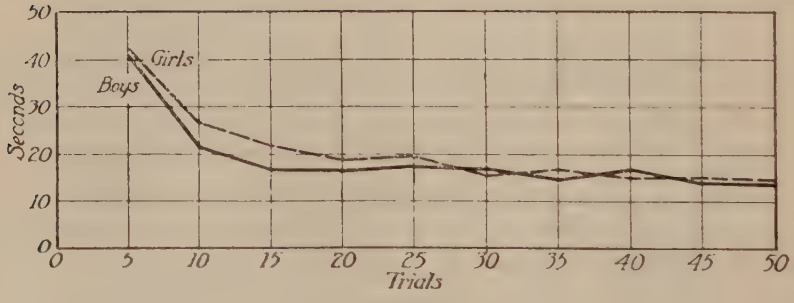


FIGURE 6

GROUP I

TABLE 16

ERROR MEDIANS BY FIVE TRIALS FOR BOYS AND GIRLS

Trials		5	10	15	20	25	30	35	40	45	50
I	Boys	3.5	0	0	0	0	.5	0	0	0	.5
	Girls	6.0	2.0	1.0	.5	.5	.5	0	0	1.0	0
II	Boys	6.5	2.0	1.0	.5	0	.5	.5	.5	0	.5
	Girls	9.0	5.0	1.5	1.0	1.0	1.0	.5	1.0	.5	1.0
III	Boys	9.5	2.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0	.5
	Girls	8.0	6.0	4.0	2.0	2.5	1.5	1.5	1.0	1.0	0

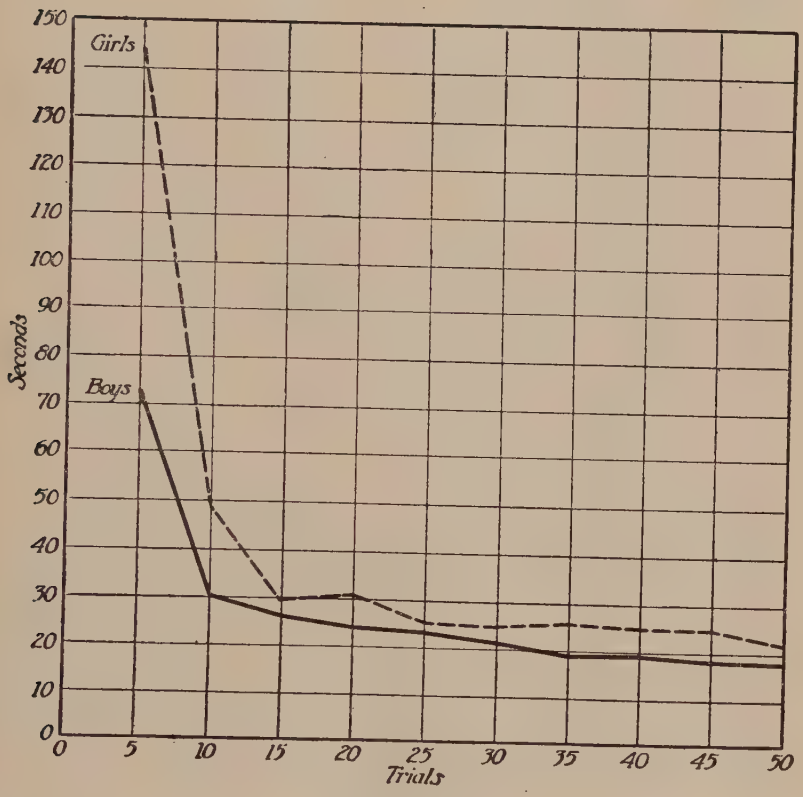


FIGURE 7

GROUP II

that boys apparently had an advantage in tests which required mechanical or motor ability and cited results from Woolley (102), Sylvester (88), Wallin (92), Young (107) with the Witmer form board and Slot Maze A (106), Easby-Graves (25), and a ring-toss experiment carried on at the University of Minnesota, Institute of Child Welfare. The results of the Wallin peg-board investigation (43) which she reported were similar.

This experiment then confirms the former investiga-

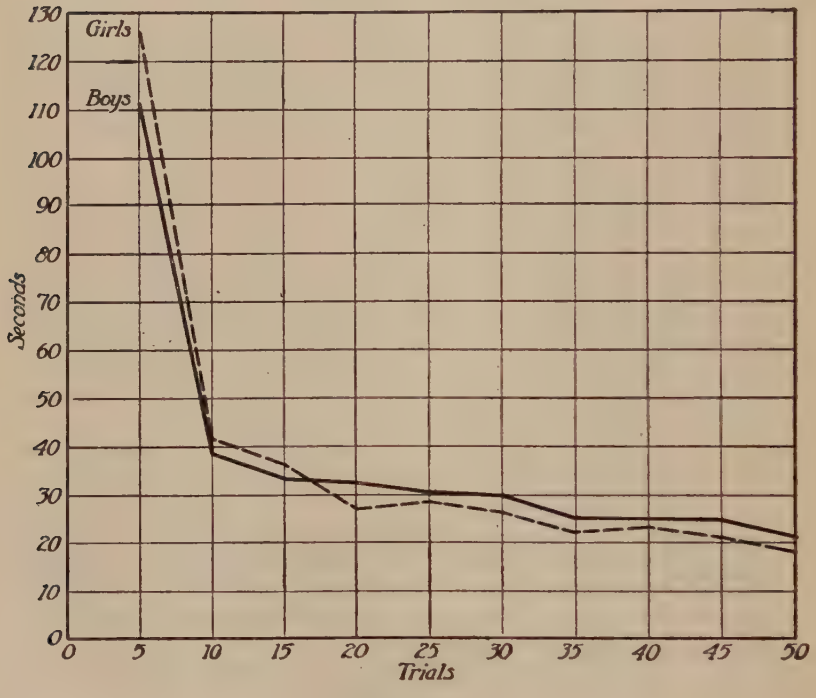


FIGURE 8
GROUP III

tions that in the initial attack at least, on a "motor" problem, the boys excel the girls and that the Young Slot Maze seems to give larger sex differences than many of the other tests.

Relation to intelligence. Table 17 gives the rank order correlations for time on first trial, total time, and total errors with I.Q. for the three age groups and for boys and girls separately. None of the correlations are high and only a few are reliable. There are no constant tendencies except that Group II gives

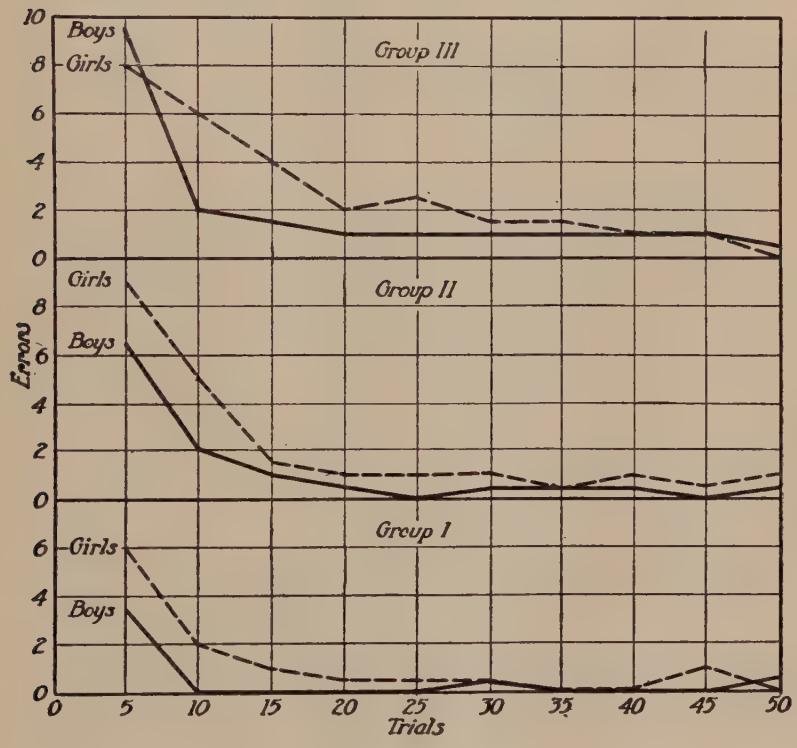


FIGURE 9

consistently higher correlations. Ability to see a maze pattern (initial trial) and know it (total time and errors) is not related very highly to the function which is measured by scores on an intelligence test.

TABLE 17
CORRELATIONS BETWEEN FIRST TRIAL, TOTAL TIME, TOTAL ERRORS, AND INTELLIGENCE

Group	No.	First trial		Total time		Total errors	
		Rho	S.E.	Rho	S.E.	Rho	S.E.
I	20	+.156	.218	0	.223	+.214	.213
Boys	10	+.010	.316	—.280	.291	+.320	.284
Girls	10	+.420	.260	+.410	.263	+.400	.265
II	20	+.410	.186	+.280	.206	+.300	.022
Boys	10	+.680	.17	+.600	.202	+.660	.178
Girls	10	+.280	.291	+.390	.268	+.390	.268
III	20	—.100	.221	+.160	.057	+.100	.221
Boys	10	—.060	.315	+.400	.265	+.150	.309
Girls	10	+.010	.316	—.200	.189	+.230	.299

Learning. Learning has been the subject of many experiments and much speculation, yet it continues to be a baffling problem. The data are confusing, and accepted methods are still to be worked out for the solution of many of the problems involved. Is there a typical form of learning curve or does it differ for different activities and different levels of ability? Does practice increase or decrease individual differences? What distribution of practice periods is best for different ages and for different materials? How are errors eliminated in activities requiring skill?

Differences in the gain made in the learning process may be expressed in several different ways. Chapman (172) advocates the use of amount of work done per unit of time, Peterson (179) suggests that the numbers so obtained are so small that they give erroneous im-

pressions of gain and lead to the misleading conclusion that practice increases individual differences. He also suggests that time units are better because the numbers are large and decrease from trial to trial. But he emphasizes the fact that increase or decrease cannot be measured in terms of absolute units. He agrees with Kincaid (177) that a measure of relative variability should be used.

The differences between the initial and best trials for the three groups are shown in Table 18. The gross gain in seconds, the percentage of gain over the initial trial and the coefficients of variability for the initial and best trials are all given, following Peterson's and Kincaid's suggestions that several methods be used.

The increase in percentage is about the same in the three groups, 91% to 93%. In terms of relative variability, practice has decreased individual differences in each case, as the coefficients of variability are much larger in the initial trial than in the best trial. This decrease was greatest in the case of the five-year-old children and least with the three-year-old group.

Single trials are affected by chance, however, and a higher reliability is obtained when the means of several trials are used, as Whitely (167), Gates (174), Kincaid (177), and Peterson (179) have each emphasized, so the first five and last five trials were also used.

When the averages of the first and last five trials are used, the coefficients of variability for Group I do not change; but when the initial trial was used for Group I, it changed the most. The explanation of this may be that the five-year-old children sense the situa-

TABLE 18

Differences between Initial and Best Trial in Seconds by Groups

Group	Initial trial		Best trial		Gross gain	Gain over initial trial	Initial Trial S.D. / mean	Best Trial S.D. / mean	Difference
	Av. time in sec.	S.D. of distribution	Av. time in sec.	S.D. of distribution	Seconds	%			
I	129.2	85.7	11.2	3.1	118.0	91.3	66.3	27.7	38.6
II	203.4	98.5	13.1	3.1	190.3	93.6	48.4	23.7	24.7
III	214.6	85.3	14.9	3.9	199.3	93.0	39.7	26.2	13.5

TABLE 19

Gain between Averages of First Five and Last Five Trials in Seconds

Group	1st 5 trials		Last 5 trials		Gain		Coefficients of variability		Difference
	Mean	S.D.	Mean	S.D.	Sec.	%	1st 5	last 5	
I	69.7	30.1	17.5	7.4	52.2	75.0	43.1	42.3	0.8
II	137.4	67.6	19.6	4.9	117.8	85.7	49.2	25.0	24.2
III	138.9	43.1	21.4	6.3	117.5	84.6	31.0	29.4	1.6

TABLE 20

COMPARISON OF HIGHEST AND LOWEST 25% BY GROUPS

Group		No. in group	Means 1st 5 trials	Means last 5 trials	Gain in sec.	Gain in %	1st 5 trials superiority in sec.	1st 5 trials superiority in %	Last 5 trials superiority in sec.	Last 5 trials superiority in %	Diff. between groups %
I. Best	25%	5	42.4	13.8	28.6	67.5					
Poorest	25%	5	117.7	15.8	101.9	86.6	75.3	63.9	2.0	12.7	51.2
II. Best	25%	5	56.9	14.7	42.2	74.2					
Poorest	25%	5	227.9	23.7	204.2	89.6	171.0	75.0	9.0	37.9	37.1
III. Best	25%	5	82.9	20.0	62.9	75.9					
Poorest	25%	5	192.2	23.9	168.3	87.6	109.3	56.9	3.9	16.3	40.6

tion or "learn" it so rapidly that an average of the first five trials takes them much farther along the learning curve than it does the four- or three-year-olds. The raw scores would indicate that this was true.

Peterson (178) in 1924 suggested the method of comparing the highest and lowest 25% of each group, using the percentage that the better group average is of the poorer group at the beginning and at the end. Table 20 gives these data.

For example, the best five in Group I started with an average of 42.4 seconds for the first five trials, while the average of the lowest 25% was 117.7 seconds, a difference of 75.3 seconds, or the best group was 63.9% better than the poorest group. In the last five trials, this superiority drops to 12.7%, a decrease of 51.2%. The poor group thus gained the most in each case, and the difference between the best and poorest 25% is decreased.

Chapman (172) criticized this method from the standpoint that when percentage is used in this way the assumption is made that the units of learning are equal. This is not true as there is no way of measuring them quantitatively. That is, a gain of two seconds towards the end of learning is different from the same gain at the beginning, but the amount of difference is not known. He advocated as a measure of improvement the correlation of the initial score with absolute improvement. Others have suggested the correlation of initial and best trial. Table 21 gives the rank order correlations for several of these.

The correlations between initial and best trials and

TABLE 21

RANK ORDER CORRELATIONS OF GAINS IN SECONDS

Group	Initial and best trial		Mean of 1st and last 5 trials		Initial and am't. gained on best		Mean of 1st 5 and amount gained	
	Rho	S.E.	Rho	S.E.	Rho	S.E.	Rho	S.E.
I	+.110	±.23	+.190	±.22	—.99	±.004	—.86	±.058
II	+.440	±.18	+.556	±.15	—.90	±.042	—.99	±.004
III	+.111	±.23	+.183	±.22	—.86	±.058	—.96	±.017

means of first five and last five are low with the exception of those of Group II. These groups are quite homogeneous and it may be that this is one explanation of the low correlations, as other investigators with older children and other skills have found a higher degree of relationship. Although there were great individual differences at the beginning of learning, they decreased to such an extent by the end that the groups were nearly at the same level within each age group. This was partly due to the physiological limit which operates in this type of skill and imposes an arbitrary limit to the possibility of learning. This is shown also in the relation of the initial score to the amount gained which gave very high negative correlations.

Elimination of errors. Table 22 shows the elimination of errors by groups and for boys and girls separately for each cul-de-sac.

Culs-de-sac nearest the goal were eliminated first, then those at the beginning and finally those in the middle. This was true of each group separately as well as for the totals of the three groups and agrees with Warden's (163) data for rats and Perkins (147) for adult human beings.

An analysis of the position of the culs-de-sac in

TABLE 22
TOTAL ERRORS FOR EACH CUL-DE-SAC BY GROUPS

	No. of children	Cul-de-sac 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Group I																
Boys	10	37	56	16	49	23	42	21	46	84	5	32	34	37	3	485
Girls	10	95	113	84	104	94	88	57	85	119	14	30	96	63	46	1088
Total	20	132	169	100	153	117	130	78	131	203	19	62	130	100	49	1573
Group II																
Boys	10	89	123	47	81	45	97	29	93	83	14	37	33	44	11	826
Girls	10	148	160	52	120	74	139	53	153	131	25	61	152	63	21	1352
Total	20	237	283	99	201	119	236	92	246	214	39	98	185	107	32	2178
Group III																
Boys	10	93	146	70	118	96	123	48	133	110	11	50	68	79	9	1154
Girls	10	162	217	104	183	158	144	84	213	215	7	130	140	142	33	1922
Total	20	255	363	174	301	254	267	132	346	315	18	180	208	221	42	3076
Total		624	815	373	655	490	633	292	723	732	(76)	340	523	428	123	6827
Rank order of elimination		8	13	4	10	6	9	2	11	12		3	7	5	1	

TABLE 23

FREQUENCY OF ERRORS IN CULS-DE-SAC TOWARDS AND AWAY FROM THE GOAL

Group		Toward the goal 2	4	6	8	9	12	Total	Av.
I	No. errors	169	153	130	131	203	130	916	152.6
	Rank	12	11	7.5	9	13	7.5		10.0
II	No. errors	283	201	236	246	214	185	1365	227.5
	Rank	13	8	10	12	9	7		9.8
III	No. errors	363	301	267	346	315	208	1800	300.0
	Rank	13	10	9	12	11	5		10.0
Total		815	655	633	723	732	523	4081	680.2
Rank		13	10	9	11	12	7		10.3

Group		Away from the goal 1	3	5	7	11	13	14	Total	Av.
I	No. errors	132	100	117	78	62	100	49	638	91.1
	Rank	10	4.5	6	3	2	4.5	1		4.4
II	No. errors	237	99	119	82	98	107	32	774	110.6
	Rank	11	4	6	2	3	5	1		4.6
III	No. errors	255	174	254	132	180	221	42	1258	179.7
	Rank	8	3	7	2	4	6	1		4.4
Total		624	373	490	292	340	428	123	2670	381.4
Rank		8	4	6	2	3	5	1		4.1

relation to the goal reveals the fact that those culs-de-sac leading in a general direction away from the goal are eliminated first, while those which lead towards the goal are the last to be eliminated.

The number of errors made in the six blind alleys leading towards the goal is 61.5% of the total number, or about 2/3. The number leading away from the goal is only 1/3 of the total. When the ranks of the order of elimination of errors are averaged, the average rank for those culs-de-sac leading towards the goal is 10.3, while the average rank for those leading away from the goal is only 4.1. As all the culs-de-sac are similar, i.e., they are continuations of the true path

and require a right angled turn to avoid them, and as the differences in errors made in those towards or away from the goal are very great, it would seem that orientation towards the goal was a decided factor in the elimination of errors.

An analysis of the errors made by the direction of the turn necessary to avoid the culs-de-sac shows that there is no significant difference in the number of errors made, or in the order of elimination, according to the direction of the turn which must be made to avoid the cul-de-sac, down, up, right, or left.

The mean number of errors per child per trial for each group shows a consistent decrease. In Group I, it has been reduced to 1.85 errors by the sixth trial, while in the case of Group II, it is 4.8 errors per child.

TABLE 24

AVERAGE ERRORS PER CHILD PER TRIAL BY GROUPS FOR FIRST SIX TRIALS AND LAST FIVE TRIALS

Group	Trials										
	1	2	3	4	5	6	46	47	48	49	50
I	7.85	7.85	6.20	4.25	3.85	1.85	.90	1.00	.90	.85	1.05
II	10.25	10.95	9.30	8.30	6.70	4.80	.75	.80	1.00	.70	.90
III	12.20	10.60	8.15	7.85	6.80	5.20	1.25	1.45	1.75	1.75	1.45

Table 24 explains the difference in results when the initial trial was compared with the best trial, or the means of the first five and the last five trials were compared. In the oldest group, the learning has progressed to such a point by the end of the fifth trial that the average of the first five, compared to the last five, covers up the differences. The younger children, on the other hand, learn more slowly, so the difference is

still great. The comparison of initial and best trial then gives the best picture of the actual learning.

TABLE 25

COMPARISON OF ERRORS ON FIRST AND SECOND HALVES OF THE MAZE BY GROUPS FOR FIRST FIVE TRIALS

Group	1st trial			2nd trial			3rd trial			4th trial			5th trial		
	1st H	2d H	Ratio	1st H	2d H	Ratio	1st H	2d H	Ratio	1st H	2d H	Ratio	1st H	2d H	Ratio
I	90	67	1.3:1	97	60	1.6:1	77	47	1.6:1	46	39	1.2:1	45	32	1.4:1
II	165	40	4.1:1	154	65	2.4:1	117	69	1.7:1	96	70	1.4:1	74	60	1.2:1
III	186	58	3.2:1	136	76	1.8:1	91	72	1.3:1	90	67	1.3:1	74	62	1.4:1

A comparison of the errors made on the halves of the maze shows a difference between the age groups. The five-year-olds make about the same ratio of errors in the two halves from the start, while the younger groups make many more errors in the first half and gradually decrease them in successive trials. Thus the older children as a group see the pattern and go clear around, while with the younger children, it is a trial-and-error process with many more errors at the beginning and a gradual decrease as the pattern is learned.

Rank order correlations between total time and total errors in the 50 trials by groups give the following results: Group I $+.437 \pm .181$, Group II $+.691 \pm .117$, Group III $+.435 \pm .186$. The correlations are influenced by the homogeneity of the groups but show a consistent relation in each group, greatest in Group II.

Picture mazes. In order to determine whether the difference between the children who make excellent records on the first trial of the man-and-shoe maze

and those who apparently learn by trial and error is due to a pattern-seeing ability, a series of maze pictures were used. The hypothesis was that if the difference between the children is in their ability to see a pattern, a situation could be set up in which pattern-seeing ability alone would be tested. The picture mazes were given to 36 of the children of the original experiment, 13 in Group I, 13 in Group II, and 10 in Group III.

The puzzles were selected after a search for hidden pictures, all of which seemed too complicated for such young children. They are from "The Mystic Maze Puzzle Drawing Book," published by Charles Graham and Co., New York. The pictures were originally designed so that the child could follow the maze path, tracing with a pencil, never crossing a line. When he got through, an animal was outlined in the maze pattern. For this experiment the outlines of the animal were drawn in black ink with broken lines so that the lines of the maze presented a confusing picture. Both the animal outline and maze lines were the same width and color as far as possible.

A preliminary series of 16 pictures was tried out on a group of 13 children. The procedure was as follows: The examiner took the child alone in a room saying, "I am going to show you a picture game. The game is to see how quickly you can tell me what it is a picture of. (Take picture No. 1 and put it face down before the child.) Now, when I turn it over, you tell me as quickly as you can what it is a picture of—Ready." The watch was started as the picture was turned over and stopped as the child spoke. The

answer was recorded. The pictures were given in the same order each time to equalize the practice effect. If he was unable to see a picture in the first one (and only 2 of 10 pre-school children were able to), he was told what the picture was and the parts pointed out until he saw it. The series was then given without further help. Credit was given if it was apparent that he saw the picture whether it was correctly named or not. The object was to find out whether he saw the outline or pattern as a picture, not whether he knew the animal or could name it.

The record for each picture was tabulated and the 10 pictures selected in the order of the number correctly named in the shortest time by the preliminary group. They were then given to the experimental group. The pictures in the order given were: (1) pig, (2) house, (3) duck, (4) camel, (5) fish, (6) cow, (7) elephant, (8) rooster, (9) stork, and (10) rabbit. The pictures left out were the rat, giraffe, monkey, squirrel, hen, and cat.

The correlations are positive and in the same direction for each group but are small and not very reliable

TABLE 26

CORRELATIONS BETWEEN PICTURE MAZES AND MAN-AND-SHOE MAZE

Group	Age	No. of cases	Time on picture maze and 1st trial on man-and-shoe S.E.	Picture maze and I.Q. S.E.	First trial man-and-shoe and I.Q. S.E.	Partial-correlations picture-maze and man-and-shoe, I.Q. constant
I	5 yrs.	13	+.407±.230	+.351±.240	+.361±.241	+.320
II	4 yrs.	13	+.580±.184	+.413±.229	+.446±.222	+.486

because of the small number of cases. In order to see whether this probable relationship might be due to the factor of intelligence, a partial correlation with intelligence held constant was figured. Apparently, there is a relation between the two which is independent of intelligence. As the children are grouped by chronological age, that factor has been equalized. Correlations with the median of the first five trials and with errors on the picture mazes were also calculated, but the first trial and average time gave the best results indicating that the differentiation was on the first trial.

It seems, keeping in mind the small number of cases, that the difference between the children who do well and those who do poorly on the initial trial may be due to a pattern-seeing ability; that this ability functions in both of these situations, and that to a certain extent this pattern-seeing ability is independent of intelligence.

Hands used. After the experiment had begun, it was decided to include the record of which hand the child used first and the number of times he shifted hands during each trial. This record does not include all the children, therefore, as some had already begun. Table 27 summarizes the data for each group separately and for the group as a whole.

In each group, the left hand is used more frequently to start with, with the exception of the girls in Group I. This would be expected, as the stylus was at the left-hand side of the maze about half-way up (see Figure 1). The five-year group showed the greatest tendency

TABLE 27

DATA ON HANDS USED AND TIMES CHANGED

Group	No. of children	Hands used first in each trial: R	%	L	%	Times hands were changed during 50 trials: Total no. of trials	No. of changes	Av. no. per child	Av. no. per trial	S.D.
I Boys	9	146	33.4	304	67.6	450	651	72.3	1.4	
Girls	7	209	59.7	141	40.3	350	460	65.7	1.3	
Total	16	355	44.4	445	55.6	800	1111	69.4	1.4	±53.2
II Boys	5	62	24.8	188	75.2	250	521	104.2	2.1	
Girls	6	62	21.7	238	79.3	300	898	149.7	2.9	
Total	11	124	22.5	426	77.5	550	1419	129.0	2.6	±34.7
III Boys	10	102	20.4	398	79.6	500	993	99.3	1.9	
Girls	10	237	47.4	263	52.6	500	863	86.3	1.7	
Total	20	339	33.9	661	66.1	1000	1856	92.8	1.8	±52.3
Grand total	47	818	34.8	1532	65.2	2350	4386	93.3	1.9	

to overcome this and start with the right hand, as the right hand was used in 44.4%, and the left in 55.6% of the trials. This might be due to the fact that the habit of right-handedness in the older group was more firmly established. The differences are shown in Table 28.

The right hand was used 21.9% more frequently by Group I than by Group II, and 10.5% more frequently by Group I than by Group III; or, in other words, almost one-half of Group I started with the

TABLE 28

STANDARD ERRORS OF THE DIFFERENCES BETWEEN GROUPS

Group	%	Right hand S.D.	Actual diff.	S.D. diff.	Ratio	Group	%	Right hand S.D.	Actual diff.	S.D. diff.	Ratio
I	44.4	.018				I	44.4	1.5			
II	22.5	.018	21.9	2.5	8.8	III	33.9	1.8	10.5	2.4	4.4

right hand, which meant that they had to reach across the maze, while only one-fifth of Group II and one-third of Group III did so.

The differences are reliable and indicate a real difference in the groups, the most probable explanation of which would seem to be the increase of the tendency of right-handedness in the older group even when the stimulus presented was on the left side.

The number of times the stylus was changed from one hand to another was also recorded.

TABLE 29

NUMBER OF TIMES HANDS WERE CHANGED

Group	No. of changes	Av. per child	S.D.	Group	Actual diff.	S.D. diff.	Ratio
I	1111	69.4	±13.3				
II	1419	129.0	±10.5	I & II	59.6	±16.9	3.5
III	1856	92.8	±12.0	I & III	23.4	±17.9	1.3

The older children change hands less often than either of the younger groups, although there was a great variation in all three groups. For example, in Group I, the range per child was from 4 times to 144 times, in Group II from 4 to 235 times, and in Group III from 8 to 175 times. The difference between Group I and Group II is three times its standard error, but between Groups I and III it is only 1.3 times its standard error.

In order to determine the relation between the number of times hands were changed and the total amount of time for running the maze, for each child, the following rank order correlations were made.

In two groups the correlations are high and indicate a relationship between the two. Group II is positive,

TABLE 30
RANK ORDER CORRELATIONS BETWEEN TOTAL TIME AND NUMBER OF TIMES CHILDREN CHANGED HANDS

Group	Rho	S.D.
I	+.703	±.126
II	+.445	±.241
III	+.659	±.097

but because of the smaller number of children, is less reliable.

There are wide individual differences in the consistency of the hand used first and the number of changes during a trial on the 50 trials. In Group I, two boys used the right hand 43 out of 50 trials, one girl used it 48 out of 50. Four boys started with the left hand from 43 to 48 times and one girl used it 47 times. Group II shows a more marked use of both hands both within a record and from child to child. No one used the same hand to start with oftener than 32 times out of 50.

The individual records for each trial also show some interesting habits. Some children were consistent in the hand used to begin throughout the 50 trials. Others started out by changing hands frequently, then used only one in the last 25 trials as speed increased. Others formed a pattern as L R L R or L R L and followed it that way practically every trial. Still others seemed to set up no particular habits, but varied in each trial. The children who made the best time changed hands less frequently and tended to use one hand consistently.

Relearning. Twenty-four children who had learned the man-and-shoe maze were to be used in the transfer experiment. The day before they started on

the new experiment, each child was given 10 trials on the man-and-shoe maze at one sitting. The time intervals between the last five trials and the relearning varied from 22 to 195 days. These intervals fall into two groups, the first one from 22 to 67 days, average 42, and the second from 129 to 195, average 159 days. There is an interval of 62 days between the two groups. The longest interval between any child's relearning then was 6½ months, the shortest, 22 days.

Both groups, with one exception, gained in the relearning over the original learning in both time and errors. The average saving in the first group was 768.6 seconds and 60.8 errors. The second group saved on the average 632.0 seconds and 34.3 errors.

The gains and losses over the record of the last 10 trials of the original learning are less consistent. In the first group, 11 children gained, on an average, 20.4% in seconds, and two children lost 19.5%. On errors, six children gained 73.9%, and five children lost on an average of 86.9%. In the second group, every child but one lost on time an average of 44.6 seconds, while one child gained 10.9%. On errors in the second group, four children showed an average gain of 15.3 errors or 28.4%. Six children lost an average of 16.7 errors or 184.7%. This shows a distinct loss in the group with the longer time intervals, but it is impossible to establish the reliability of this difference. The assumption is made in getting the standard error of a percentage that it is a proportion, while in this method there are gains averaging more than 100%. Apparently the longer interval did interfere with the

relearning and cause greater loss in time, and perhaps in errors, than the shorter intervals.

Conclusions. Three groups of children with 10 boys and 10 girls in each group at each of 3 age levels, 3, 4, and 5 years, were used in a learning experiment on the Young Slot Maze A. Each child had 5 trials per day, 5 days a week for 2 weeks, making a total of 50 trials per child or 3000 trials for the whole group. Twenty-eight children completed the experiment as planned, 32 children had one or more absences ranging from 1 to 18 days.

Several methods of motivation were used; the maze was called a game and the children were invited to come and play the "man-and-shoe game." The toy man and shoe, colored gayly, were attractive and held the children's interest. The trials were timed and the children encouraged to make a fine record. Outlines of the man and of the shoe were drawn on colored papers, while the child watched, and then were given to him as a reward. The children were interested to such an extent that a year later they frequently asked if they might come and play "man and shoe."

Using trials 5-50, odd versus even, the reliability by Pearsonian r was $+.618\pm.018$ (S.E.) for the entire group of 60 children. By separate groups it was $+.559\pm.032$ (S.E.) for Group I, $+.646\pm.027$ (S.E.) for Group II, and $+.605\pm.029$ (S.E.) for Group III. These correspond closely to Hunter's results with adults on a stylus maze.

Considering the maze as a test and computing reliability by the sum of the odd and even trials for both

time and errors, reliability coefficients similar to those reported by Stone and Nyswander for rats were obtained, +.8 to +.9.

Analysis of the learning curves by medians of each five trials showed a steeply sloped curve with the three age groups clearly separated at the beginning and no overlapping except in the girls in Groups II and III after the 35th trial. This overlapping of the girls in Groups II and III was due to the fact that 16 three-year-old girls were tried out in order to get 10 who could do the experiment. Therefore, they were highly selected and approached the four-year-old group in maze-learning ability.

A comparison of initial and best trials by groups and of total time and errors showed clear age differences again. Thus the experiment confirmed the conclusions of other investigators using other skills that "motor" ability or in this case maze-learning ability increased with age for three-, four-, and five-year-old children.

Distinct sex differences on the initial and second trials were found at each of the three age levels; this confirmed previous results by Young and Easby-Graves. However, as learning continued through the 50 trials, these sex differences disappeared. An explanation was offered that perhaps the initial differences were due to a difference in "pattern-seeing" ability, which is not operative after the pattern is learned, and that the final trials are limited by the physiological ability or motor coordination in which there is no difference between the sexes in young children, according to Wellman.

There was apparently very little relation between ability on intelligence tests and learning the maze whether first trial, total time, or total errors were used. The correlations were low and only a few were reliable. The range of Rho was from —.20 to +.68, but only five were twice their standard errors.

The amount gained in time during the 50 trials by the three age groups was measured by gross gain, percentage gain over initial trial, and coefficients of variability. Both initial and best trials and the means of the first five and last five trials were used. In each case the individual differences were decreased by practice. When the upper and lower 25% of each group were compared using the means of the first five and last five trials, the lower group gained the most in each case and the two groups approached each other quite closely.

Rank order correlations of initial trial and amount gained over best trial were from +.11 to +.44 which is lower than many investigators report. For averages of first five and last five trials, the correlations were +.18 to +.56. As the groups are very homogeneous, slight changes in score would change the rank and this may account for the low correlations. Correlations of the average of first five trials with amount gained over last five and of initial trial with amount gained over best trial were negative and ranged from —.86 to —.99.

Gain in errors was least in the five-year-old group when measured by percentage gain over initial trial, as they made the fewest errors to begin with.

There was no backward elimination of errors. The last cul-de-sac was the first eliminated in each group, No. 11 was eliminated second by one group and third by all the groups together, No. 3 next. There was a general tendency for the last culs-de-sac to be eliminated first, and the others varied.

Individual children formed position habits which persisted throughout the 50 trials in many cases, but the habits varied from child to child.

An analysis of culs-de-sac showed that two-thirds as many errors were made in culs-de-sac leading towards the goal as in those leading away from the goal. The average rank for culs-de-sac leading towards the goal was 10.3, for the others 4.1. This was true of each age group as well as the total group. The average number of errors for those towards the goal was 680.2, while 381.4 was the number for those leading away from the goal.

The direction of the turn in order to avoid a blind alley, up or down, right or left, made no difference. The average rank for those requiring a down movement was 6.3, up 6.5, right 9.6, and left 5.5. The average number of errors per blind was 492.5 for down, 465.2 for up, 667.3 for right, and 459 for left.

The mean number of errors per child per trial decreased from the first to the 50th trial very markedly in each group but most rapidly in Group I where it had reached 1.85 errors per child by the sixth trial. In Group II this was 4.8 errors, and 5.2 in Group III. Thus the oldest children reduced the number of errors much more rapidly than the younger groups. This is

also shown when the maze is divided into halves. The oldest group made a ratio of 1.3 to 1 between errors in the first half and second half, the four-year-old children, 4.1 to 1 in the first trial. The older children made fewer errors in the first half than the younger children, which shows again that they learned the whole pattern more by insight, while the younger children used trial and error methods to a greater extent at the beginning of learning.

In order to determine what factors were at work to cause the wide individual differences in children of the same age and intelligence on the initial trial, a series of maze pictures, pictures outlined in broken lines and complicated by maze paths, were used. Correlations between the first trial on the "man-and-shoe maze" and the average time on the picture mazes were $+.40 \pm .23$[1] for 13 children in Group I and $+.580 \pm .184$ for 13 children in Group II. Correlations between test intelligence measured in terms of I.Q. and picture maze were $+.351 \pm .240$ and $+.413 \pm .229$; between first trial "man-and-shoe maze" and I.Q. $+.361 \pm .241$ and $+.446 \pm .222$. When intelligence was held constant, the correlations still remained $+.32$ and $+.486$. The difference, then, may be due in part to a pattern-seeing ability which apparently functioned in both the first trials of the "man-and-shoe maze" and the ability to see the picture mazes. It appeared to be partly independent of test intelligence.

The five-year group showed the greatest tendency to use the right hand first in spite of the fact that the sty-

[1]S.E. in each case.

lus was at the left side of the maze at the beginning. The younger children used the left hand to start with more frequently. This may be interpreted as showing the greater effect of the habit of right-handedness on the oldest group.

The oldest group also changed hands less frequently during a trial than did the younger children. The correlations between the number of times hands were changed and the total time for learning were $+.703 \pm .126$ for Group I, $+.445 \pm .241$ for Group II, and $+.659 \pm .097$ for Group III. Thus the children who made the best speed tended to use the same hand throughout the trial.

Twenty-four children who had learned the "man-and-shoe maze" relearned it with 10 successive trials on one day after intervals of 22 to 195 days. They fall into two groups, one averaging a 42-day interval, the other a 159-day interval. Both groups did better on the relearning than on the original learning, but the second group with the longer time interval lost more in time and errors than the first group. The actual average difference was 111.8 seconds and 4.3 errors. The time difference was 5.6 times its S.E., but the error difference was only .6 of its S.E. Thus the longer lapse of time interfered more with relearning and affected speed more than errors.

III

TRANSFER AND INTERFERENCE ON A MAZE IN WHICH THE VISUAL CUES ARE ALIKE

Experimental Procedure. After determining that little children can learn a simple pattern on a maze, it was decided to attack intensively a more specific problem, that of interference or transfer on a series of maze patterns using paired groups. The maze used, described by McGinnis (141), is a modification of one designed by Carr to use for study of the problem of visual guidance in maze learning (see Figure 10). The maze is 12 inches square and is made of hard black vulcanized fiber board with 25 squares and a border. The pattern consists of grooves formed in the following way. A small piece of fiber board lies between the center of each square and the base. Two bolts, the heads of which lie on one diagonal of the square, hold the inserted fiber board and attach it to the base. They are well within the square and do not interfere with the grooves. Since the border is raised by long narrow strips on the outside edge, a grooved track is also left between the squares and the border (see Figure 10*b*).

The stylus is turned out of one piece of brass and consists of a cylindrical knicked handle, a short narrow neck, and a circular disc, ½ inch in diameter at right angles to the handle. The disc slides freely through the grooves. The passage of the stylus is blocked at

appropriate points by pairs of bolts screwed through the base from below, one into each side of the groove, where they stop the stylus without being visible from above. Shifting or removing the bolts changes the pattern.

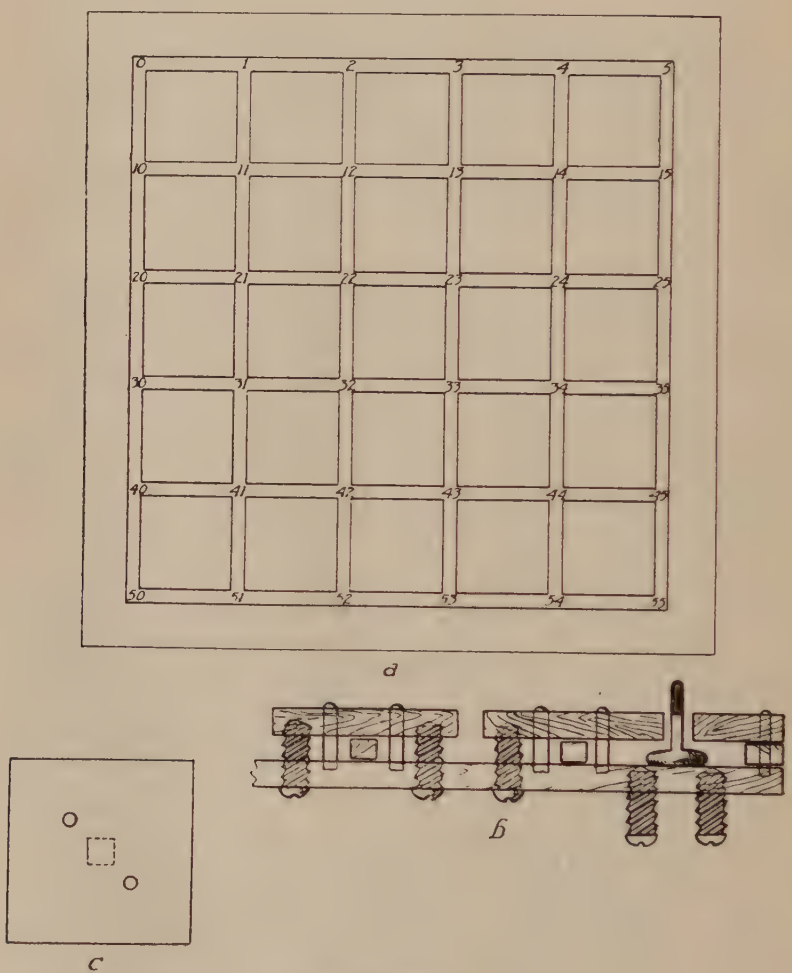


FIGURE 10

The non-conductivity of the material permits the insertion of wires leading to an electric bell. An ordinary door bell was used which made it easier to take the time and also made it a game for the children.

As all the cues are similar, it is more difficult to record errors on this maze. The following scheme was finally used (see Figure 10*a*). Each line of the pattern was numbered by 10's as 0, 10, 20, 30, 40, 50, thus each junction point had a number. The four errors were lettered A, B, C, D, thus 11 D means the stylus was put into the "west" blind alley at 11; 12 C means the stylus went into the "south" blind alley at 12, etc.

The directions are as follows: The stylus was placed at the beginning before the child came in. He was seated directly in front of the maze. The box with the batteries and bell was under the table at one side. The examiner said, "This is a bell game. When you move this (pushing the stylus) to the right place a bell will ring." The maze was then screened with cardboard and the examiner rang the bell several times so the child would be used to it and not jump or be frightened. The stylus was moved back to the beginning and the maze uncovered. "Now let us see how quickly you can make the bell ring." Time was taken as before, from the time the child actually took the stylus and started to move it until the bell rang or until he was in the blind alley at the goal.

Groups I and II were paired and each child had 40 trials on Maze-patterns A and B during the summer session of 1927. Group I had A first then B, Group

TABLE 31

PLAN OF TRANSFER EXPERIMENT

Group	No. of children	Maze pattern	No. of trials	Days between	Maze pattern	No. of trials	Days between	Maze pattern	No. of trials	Days between	Maze pattern	No. of trials
I	6	A	40	4	B	40						
II	6	B	40	2	A	40						
III	6	A	50	5	B	50	47	C	50	2	D	50
IV	6	B	50	1	A	50	46	D	50	3	C	50

II, B and then A. In the fall of 1927, two more paired groups, III and IV, were selected, given 50 trials each on Maze-patterns A and B, then after the Christmas holidays had two more patterns, C and D, 50 trials each. Thus, 24 children had 3260 trials on four patterns (one boy in Group IV moved out of town before he had C and D).

Composition of Groups.

Experimental results. Table 32 shows the composition of the groups. Each child in this experiment had been a subject in the "man-and-shoe" experiment and had 10 trials of relearning on the "man-and-shoe" maze the day before beginning this experiment. (See section on *Relearning,* page 57.)

All ages are calculated from the date of beginning

TABLE 32

COMPOSITION OF GROUPS IN TRANSFER EXPERIMENT

Group	C.A. in mo. Mean	S.D.	M.A. Mean	S.D.	I.Q. on Kuhlman Mean	S.D.	Initial trial Young Mean	S.D.	Best trial Young maze Mean	S.D.
I	48.5	5.8	57.7	12.6	117.7	15.9	232.1	94.8	13.9	2.8
II	49.8	5.3	58.3	7.5	117.0	8.8	158.7	84.0	13.8	1.5
III	46.5	7.5	54.7	14.0	116.5	14.0	208.5	92.0	16.4	3.6
IV	47.0	6.1	56.0	11.9	118.9	15.4	202.1	107.9	13.5	4.5

the first pattern. The differences in I.Q. are very small, .7 point between I and II and 2.4 points between III and IV. The individual pairs are also matched as closely as possible on chronological age and I.Q. The greatest difference in chronological age in any pair is five months, the greatest difference in I.Q. is 24 points. The other pairs differed from 2 to 9 points in I.Q.

Time intervals. The first transfer experiment was made during the summer session of 1927. There were three children out of the 12 who had absences during the experiment, two for one day each and one child for two days.

The time intervals in the second experiment were badly broken up by absences due to infectious diseases and colds. In every case where it was possible, the maze was taken to the home. Other children could not be substituted because of the paired groups and the fact that the child had had a certain order of previous experience on other patterns. The data are used, then, as though they had been collected under the standard conditions of the experiment, but it must be kept in mind that due to uncontrollable factors, such conditions were not always maintained. This is an inevitable consequence of an experiment with very young children which requires their daily cooperation over a period of weeks. Children in Groups III and IV made a total of 200 trials on successive patterns with five trials per day, five days a week. Christmas holidays intervened between Patterns A and B and C and D in both groups.

Maze patterns. Four patterns were used on the concealed-cue maze. All four patterns covered the same distance, 14 squares (see Figure 11). Patterns A and B differed in that part of the path in B ran along the outer edge of the maze, hence there were

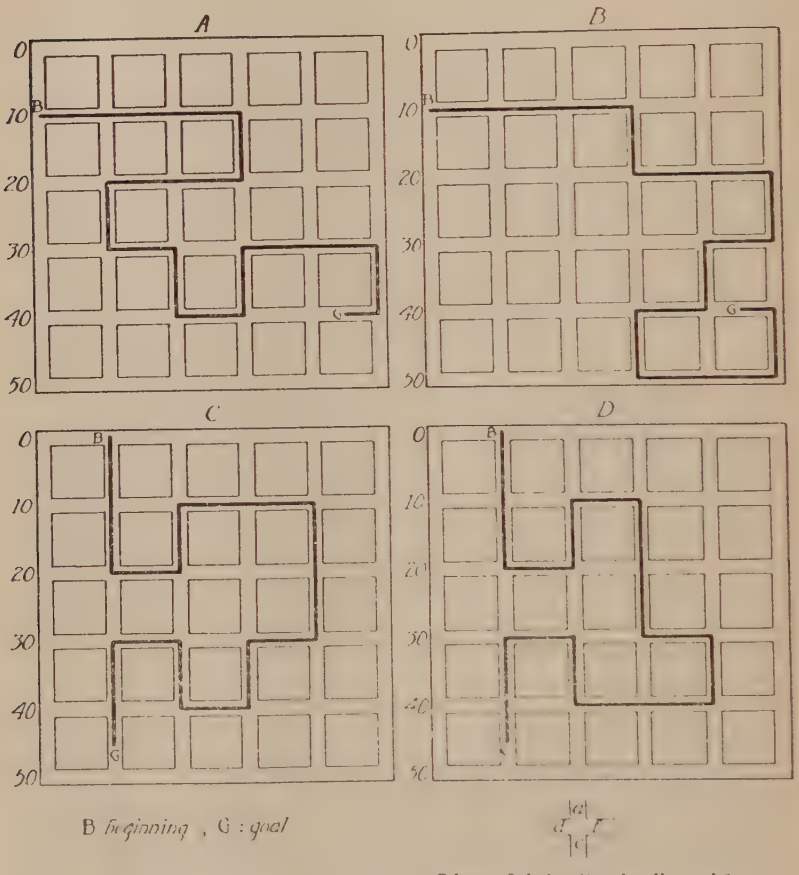


FIGURE 11

MAZE PATTERNS

fewer chances for error. Also it was easier because the child could orient himself with the outer edge of the maze. In Patterns C and D this was remedied by having the pattern in the center of the maze, also the right and left turns and possible errors were equalized.

TABLE 33
ANALYSIS OF PATTERNS (SEE FIGURE 11)

Pattern	Distance	Squares to the right	Squares to the left	Down	Up	Possible errors	Perseverative errors	Same squares	Opposite squares	Beginning no.	Goal no.
A	14 sq.	7	2	4	1	28	9	8	6	10	45
B	14 sq.	7	2	4	1	23	7	8	6	10	45
C	14 sq.	3	3	6	2	30	10	9	5	1	41
D	14 sq.	3	3	6	2	30	10	9	5	1	41

Motivation. To make the maze as interesting as possible, an electric door bell was attached to the goal; this rang when the stylus touched the goal. Then the maze was called a bell game. Most of the children liked to ring it.

The same methods of encouragement and praise were used as before, and the reward was a picture of the bell and battery or maze drawn while the child looked on. This did not appeal as strongly as the man and shoe, although the children were interested. Also because the experiment, especially with Groups III and IV, lasted over such a long period of time, it was more difficult to hold interest. However, no one refused and there was no difficulty with most of the children. The five trials took only a few minutes and the interest in ringing the bell held over from one trial to another.

Reliability. Correlations for both time and errors

of trials 5-50, odd versus even, were made for the first pattern for each group. The correlations range from +.32 to +.66. There is little difference in the reliability for time and errors, the correlations for time averaging +.45, and for errors, +.46. The correlations are on the average lower than those for the Young Slot Maze A. This would seem to indicate that maze running with visual cues similar was more of a trial and error process than when the situation allowed "insight."

TABLE 34

RELIABILITY COEFFICIENTS FOR TRIALS 5-50—ODD VERSUS EVEN

Group	Time		Errors	
	r	S.E.	*r*	S.E.
IA	.509	.296	.477	.309
IIB	.368	.346	.370	.345
IIIA	.627	.243	.325	.358
IVB	.408	.333	.508	.297
IIIC	.339	.354	.447	.320
IVD	.465	.314	.661	.225

Transfer and interference. Before transfer or interference could be measured, it was necessary to equate for the differences in the difficulty of the patterns. While the distance was the same in each, the number of possible errors in B was five less than in A, due to the fact that the path went along the outer edge of the maze. This also undoubtedly made orientation easier. In order to determine the relative difficulty of A and B, the total time for each, regardless of position, was added. Then the total time for A was divided by total time for B, giving the ratio of B in terms of A. This was done for time and errors separately for Experiment I and II and for both together. See Table 35.

TABLE 35

METHOD OF EQUATING FOR DIFFICULTY OF PATTERNS

Group	No. of ch.	No. of trials	Av. total time A	Av. total time B	A/B Ratio	Av. total time C	Av. total time D	C/D Ratio	Av. total errors A	Av. total errors B	A/B Ratio	Av. total errors C	Av. total errors D	C/D Ratio
I	6	40	1875.5	663.9					354.5	159.5				
II	6	40	1226.0	846.3					292.2	169.7				
Total			3101.5	1510.2	2.05				646.7	329.2	1.96			
III	6	50	1934.5	719.9		1034.3	725.7		533.5	218.8		323.7	249.5	
IV	6	50	1011.4	914.5		598.1	883.9		361.0	243.5		199.4	310.4	
Total			2945.9	1634.4	1.80				894.5	462.3	1.93			
Grand total			6047.4	3144.6	1.9	1632.4	1609.6	1.01	1541.2	791.5	1.95	523.1	559.9	.93

The ratio for time in the first experiment was 2.05, for the second, 1.8. The average for the two was 1.9 for time. For errors, it was 1.96 for Experiment I, and 1.93 for II, averaging 1.95. For C and D, the ratio for time was 1.01 and for errors .93. The ratio of 1.9 was used as the measure of difficulty of A in terms of B and all the B scores were multiplied by that factor before comparisons were made for transfer or interference. As the ratios for C and D were practically one, they were considered of the same degree of difficulty.

Table 36 shows the comparison of total time and errors for each maze pattern when the B scores have been multiplied by 1.9, the factor for the difference in the difficulty of patterns. The standard deviations, amount saved in time, and percentage for each pattern are also given.

In every case, regardless of the order of the patterns, transfer occurred if it is measured either by the actual or percentage difference between each pattern. For example, Group III, who learned the patterns in order A, B, C, D, gained 566.7 seconds from A to B, 333.5 seconds from B to C, and 308.6 from C to D. Group IV, who learned them in the order B, A, D, C, gained 726.2 seconds from B to A, 127.5 from A to D, and 285.8 seconds from D to C. This is true in spite of the fact that the patterns were theoretically set up to produce interference.

The actual savings in errors were less but follow the same general direction.

When the gain was expressed in terms of the first

TABLE 36
Amount of Transfer with Time Records on Four Maze Patterns

Group	No. of trials	A Sec.	A S.D.	B* Sec.	B* S.D.	Am't. saved in sec.	% saved	C Sec.	C S.D.	Am't. saved in sec.	% saved	D Sec.	D S.D.	Am't. saved in sec.	% saved
I	40	1875.5	705.6	1261.4	186.8	614.1	32.7								
		B*		A											
II	40	1607.9	270.6	1226.0	342.9	381.9	23.8								
Total		3483.4		2487.4		996.0	28.6								
		A		B*											
III	50	1934.5	609.1	1367.8	182.4	566.7	29.3	1034.3	139.1	333.5	24.4	725.7	135.4	308.6	29.8
		B*		A				D				C			
IV	50	1737.6	502.2	1011.4	391.2	726.2	41.8	883.9	308.0	127.5	12.6	598.1	189.3	285.8	32.3
Total		3672.1		2379.2		1292.9	35.2	1918.2		461.0	19.4	1323.8		594.4	30.9

*Equated for difficulty by multiplying by factor 1.9.

TABLE 37
Amount of Transfer with Errors on Four Maze Patterns

Group	No. of trials	A Errors	A S.D.	B* Errors	B* S.D.	Am't. saved	% saved	C Errors	C S.D.	Am't. saved	% saved	D Errors	D S.D.	Am't. saved	% saved
I	40	354.5	122.3	303.5	45.9	51.0	14.4								
		B*		A											
II	40	322.4	68.0	292.2	56.6	30.2	9.4								
Total		676.9		595.7		81.2	11.9								
		A		B*				C				D			
III	50	533.5	159.0	415.9	56.9	117.6	22.0	323.7	74.8	92.2	22.0	249.5	96.2	74.2	22.9
		B*		A				D				C			
IV	50	462.7	133.8	361.0	138.5	101.7	21.9	310.4	139.2	50.6	14.0	199.4	85.1	111.0	35.8
Total		996.2		776.9		219.3	22.0	634.1		142.8	18.4	448.9		185.2	29.2

*Equated for difficulty by multiplying by factor 1.9.

pattern in each case, the transfer was even more clearly shown.

TABLE 38

AMOUNT AND PERCENTAGE OF GAIN OVER FIRST PATTERN

Group	Time						Errors					
	AB*		AC		AD		AB*		AC		AD	
	Am't. gained	% gained	Am't. gained	% gained	Am't. gained	% gained	Am't. gained	% gained	Am't. gained	% gained	Am't. gained	% gained
III	566.7	29.3	900.2	46.5	1208.8	62.5	117.6	22.0	209.8	39.3	284.0	53.2
	B*A		B*D		B*C		B*A		B*D		B*C	
IV	726.2	41.8	853.7	49.1	1139.5	65.6	101.7	21.9	152.3	32.9	263.3	59.1

*Equated for difficulty by multiplying by factor 1.9.

The chief difference was between A and B and B and A for time, where Group IV gained more than Group III. Outside of that, the percentages for the two groups corresponded closely for both time and errors.

These results confirm those of previous workers with rats and adults who found that transfer occurred from pattern to pattern when measured by total time and errors [Webb (166), Wiltbank (168), Hunter (129)].

In every case the means of the first five trials of the new pattern were less than the means of the first five on the old pattern, but the means of the first five were greater than the means of the last five trials of the preceding pattern, which shows the temporary interference of the new situation. The means of the last five trials showed a decrease with each succeeding pattern also.

Children then profit by previous experience in the maze situation as do rats and adults. The only interference developed was temporary and occurred at the beginning of the new pattern and was not great enough

in any group to affect the total results. Control groups for Patterns A and B showed greater time and errors in each case. Control groups were not available for C and D, but these gave similar results when given in reverse order to two groups with different previous experience.

Relation to intelligence. Although the correlations of errors with intelligence on the first trial of the Young Slot Maze were low, +.10 to +.66, the comparison between the attack on the two mazes reveals some significant differences.

TABLE 39

CORRELATION OF ERRORS WITH INTELLIGENCE ON FIRST TRIALS ON YOUNG SLOT MAZE AND CONCEALED-CUE MAZE

Groups	No. of ch.	I.Q. and first trial on Young Slot Maze		I.Q. and first trial on concealed cue maze		1st trial on Young and concealed-cue mazes	
		Rho	S.E.	Rho	S.E.	Rho	S.E.
I, III A	12	+.419	±.236	—.024	±.285	—.015	±.285
II, IV B	12	+.567	±.194	—.04	±.285	+.161	±.278

Only the first maze patterns for each group and the first trial were used. Groups I and III were combined. Both groups show a higher degree of relationship between errors and intelligence on the first trial of Young Slot Maze than on the concealed-cue maze. On the latter, there is no relationship. There is also no relation between the two mazes. This seems to substantiate Köhler's assertion that animals can show insight only when the situation is such that it can be used. In the concealed-cue maze, there is no opportunity for intelligence to function; it has to be a trial-and-error performance at least for the first trial. In

the Young Slot Maze where the situation permitted a pattern-seeing ability there was a higher correlation between intelligence and the number of errors.

Learning. Data for each pattern on the initial and best trial, the means of the first five and last five trials, the amount gained, percentage gained, and the coefficients of variability for both time and errors were calculated. In general, individual differences decreased as learning proceeded. The percentage gains were higher for initial and best trials than for the means of the first and last five trials, due to the fact that learning had progressed during the five trials and there was less possible gain to be made.

Effect of distribution of practice on identical and diverse errors. In 1917 Lashley (137) published a study of the effect of distribution of practice on the rate of learning of rats on a maze with 12 possible errors, in which he compared the relative number of diverse and identical errors occurring in successive trials on the same day with those on the last trial of one day and the first trial of the next day. He paired the last trial of one day and the first of the next day with two successive trials on the same day having the same number of errors. Only trials containing more than two errors were used. In order to see whether the same factor was operative in the learning of children as in rats, the data were treated in exactly the same way.

Lashley says, "comparison of the number of duplicate errors cannot be made directly, owing to the variations in the number of errors made in different trials

and the consequent difference in the probability of chance duplication. Thus if 9 of a possible 12 errors are made in each of 2 successive trials a larger percentage of identical errors is to be expected from pure chance than if only three errors are made in each trial.

"The method used gives essentially a random sample of the two kinds of pairs of successive trials and the role of chance may be disregarded, since it should be the same for both pairs. The relative proportion between duplicate and distinct errors may be considered the result of the time intervening between the successive trials. Only wrong turns were counted and only one error at each turn."

TABLE 40

COMPARISON OF IDENTICAL AND DIVERSE ERRORS ON SUCCESSIVE TRIALS AND SUCCESSIVE DAYS

No. of pairs	Successive trials: 1st trial of pair	Last trial of pair	Pairs of identical errors	Diverse errors	% Diverse	Successive days: Last trial of one day	1st trial of next day	Pairs of identical errors	Diverse errors	% Diverse
Lashley										
175	463	524	274	439	44.48	463	524	247	493	49.95
Present experiment										
122	615	610	340	545	44.49	615	610	304	617	50.37

Thus the trials separated by a 24-hour interval included 10% fewer duplicate errors in Lashley's data and 11.8% in the present experiment. Lashley concluded, "The trials separated by a 24 hour interval are thus seen to include fewer duplicate errors than those without intervening time. A greater diversity of activity occurs when successive trials are separated by a considerable interval of time than when they follow

TABLE 41
Elimination of Errors

Group	No. of trials	Culs-de-sac 10	11	12	13	23	22	21	31	32	42	43	33	34	A 35	C 45	Total
I A	40	52	119	130	277	442	162	117	211	209	113	179	59	41	9	7	2127
Rank		4	8	9	14	15	10	7	13	12	6	11	5	3	2	1	
II A	40	27	90	110	237	367	147	83	132	173	94	200	44	43	4	3	1754
Rank		3	7	9	14	15	11	6	10	12	8	13	5	4	2	1	
III A	50	71	247	217	394	686	264	185	280	309	147	239	65	45	14	38	3201
Rank		5	10	8	14	15	11	7	12	13	6	9	4	3	1	2	
IV A	50	5	32	62	261	448	164	150	197	261	143	225	53	22	7	136	2166
Rank		1	4	6	13.5	15	10	9	11	13.5	8	12	5	3	2	7	
Av. of ranks		3.1	9.8	8	13.8	15	10.5	7.3	11.5	12.6	7	11.3	4.7	3.3	1.7	2.7	
Rank		3	9	8	14	15	10	7	12	13	6	11	5	4	1	2	

TABLE 42
Elimination of Errors

Group	No. of trials	Culs-de-sac 10	11	12	13	23	24	25A	35C	34	44	43	53D	54A	45A	Total
I B	40	8	41	57	193	214	102	4	124	59	80	47	6	18	5	957
Rank		3	5	7	12	13	10		11	8	9	6	2	4	1	
II B	40	16	99	96	159	163	80	3	179	50	123	33	10	5	3	1019
Rank		4	9	8	11	12	7		13	6	10	5	3	2	1	
III B	50	8	60	85	230	256	140	5	152	106	158	55	10	9	39	1313
Rank		1	6	7	12	13	9		11	8	10	5	3	2	4	
IV B	50	36	58	82	278	231	103	11	243	95	195	69	12	7	41	1461
Rank		3	5	7	13	11	9		12	8	10	6	2	1	4	
Av. of ranks		2.8	6.3	7.3	12	12.3	8.7		11.7	7.5	9.7	5.5	2.5	2.3	2.5	
Rank		4	6	7	12	13	9		11	8	10	5	2.5	1	2.5	

TABLE 43

Elimination of Errors

Group	No. of trials	Culs-de-sac 1	11	21	22	12	13	14	24	34	33	43	42	32	31	41	Total
III C	50	40	238	246	471	46	90	145	95	163	106	116	123	29	29	7	1942
Rank		4	13	14	15	5	6	11	7	12	8	9	10	2.5	2.5	1	
IV C	50	4	51	151	461	3	101	85	82	133	83	63	56	8	8	8	997
Rank		1	6	14	15	2	12	11	9	13	10	8	7	4	4	4	
		Culs-de-sac 1	11	21	22	12	13	23	35	34	44	43	42	32	31	41	
IV D	50	2	104	207	346	33	143	124	175	102	88	61	124	16	19	10	1554
Rank		1	9	14	15	5	12	10.5	13	8	7	6	10.5	3	4	2	
III D	50	1	43	212	322	8	216	69	271	66	98	66	89	17	33	1	1507
Rank		1.5	6	12	15	3	13	9	14	7.5	11	7.5	10	4	5	1.5	
Av. rank		1.8	8.5	13.5	15	3.7	8.7	10.4	10.7	10	9	7.6	9.3	3.4	3.9	2.1	
Rank		1	7	14	15	4	8	12	13	11	9	6	10	3	5	2	

each other immediately. Persistence of errors through prolonged periods of practice seems adequate to account for the retardation of learning due to concentrated practice."

The fact that the same divergency in percentage of duplicate and diverse errors was found in maze learning with young children is even more significant, since there were a greater number of errors possible in the patterns used. Thus the chances for the duplicate and diverse errors being equal in number, which he stated were one to eight for his maze, would be even less in this experiment and the actual differences found would be more striking. The dropping out of error habits during the time of no practice, which Lashley had already demonstrated for rats learning the maze, is thus clearly shown in the maze learning of young children.

Elimination of errors. Tables 41, 42, and 43 give the total errors for each position on the maze. Two culs-de-sac were combined as 10A and C because it was impossible to say which of those errors came first as they were equidistant from the goal and the beginning. There was no backward elimination of errors in any separate pattern or in the averages of the same pattern by different groups. The culs-de-sac at the end nearest the goal are eliminated first; those at the beginning next; those next the beginning, last (see figures 10 and 11). Culs-de-sac 13 and 23 are the last to be eliminated in both Patterns A and B, and 21 and 22, which are in nearly the same relative position, are the last in Patterns C and D by both groups. Thus without exception, the last and first culs-de-sac are eliminated before a group closer to the beginning.

Conclusions. Two experiments with two paired groups of 12 children each were made with four patterns on a maze in which the true path was blocked from below and the visual cues were similar.

The first group in the first experiment had 40 trials on each of two patterns, A and B. The other group reversed the order. In the second experiment, two other paired groups had 50 trials each with four patterns, A, B, C, D. The second group took the patterns in the order, B, A, D, C. Thus, 24 children had 3,260 trials on four patterns.

The groups were matched in chronological age, mental age, I.Q., sex, and in initial and last trials on the Young Slot Maze experiment. The largest difference between the two paired groups was 1.3 months in chronological age, 2.4 points in I.Q.; between two paired individuals within a group the largest difference was 5 months in chronological age and 24 points in I.Q.

Five trials per day, five days a week omitting Saturday and Sunday, were the time intervals. In the first experiment, three children out of 12 had absences amounting to four days. In the second experiment, where four patterns were used with a total of 200 trials for each child, there were many absences due to colds, infectious diseases, and bad weather.

The maze was made into a game for the children by attaching a bell which rang when the stylus reached the goal. Pictures of the bell and the maze were drawn as the child looked on, and were given as a reward. The children were praised for good trials and urged to beat their own records.

Coefficients of reliability for trials 5-40, or 5-50, odd versus even, for each pattern, ranged from +.3 to +.6. They averaged for both time and errors about +.45. Only two were below +.4.

The four patterns were equated for difficulty by computing the ratio between them. B was easier than A and all the B scores were equated by multiplying by the factor 1.9. C and D were apparently equal in difficulty.

In every case, regardless of the order in which the pattern was given, there was marked transfer from each pattern to the succeeding one when the differences in total time and errors were used as a measure of transfer. This confirmed previous results by Webb, Wiltbank, Hunter, and others. Thus, in spite of the fact that the patterns were designed to produce a maximum of interference by using exactly opposite directions in certain turns and similar ones in others, no interference was shown. The young child, as in the case of the rat and the adult, profited from previous maze experience with each succeeding pattern.

If the last trial of one pattern and the first of the next, or the means of the last five and first five trials were used, a temporary interference was shown. But if the means of the first five trials were compared with the means of the first five trials of the previous pattern, again there was transfer from one pattern to another.

The correlations of the first trials or means of the first five trials of the first pattern with test intelligence were low or zero. Where Groups I and III, and II and IV were combined, the correlations were —.024

and —.04. When these children's error records on the first trial on the Young Slot Maze were correlated with intelligence, the correlations were +.419 and +.567. When first trial on the McGinnis Maze was correlated with intelligence, the correlations were around zero. There was practically no relation between first trials on the two types of mazes. This seemed to show that in the first trial on a maze where insight could be used the relation to intelligence was positive, while in one in which only the trial-and-error method was possible, intelligence was not a decided factor.

Individual differences were decreased by learning when measured by the coefficients of variability for initial and best trials, or for the means of the first five and last five trials.

A comparison of identical and diverse errors on successive days with successive trials on the same day confirmed Lashley's 1917 study of maze learning of rats in which he found 10% fewer duplicate errors in trials separated by a 24-hour interval. Young children also make fewer identical errors, and thus Lashley's theory of the effect of periods of no practice on the elimination of errors is true for children as well as for rats. The results were even more significant, since this maze had more chances for errors than did his.

There was no backward elimination of errors. Instead, as in the previous experiment, the culs-de-sac nearest the goal and the beginning were eliminated first. This was true of each pattern separately or of the averages by groups.

The average errors per child per trial showed a decrease from the first to the last trials in each group.

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L'ACQUISITION ET LE CONFLIT DES HABITUDES MOTRICES CHEZ LES JEUNES ENFANTS

(Résumé)

On a donné à 20 enfants à chacun des trois niveaux d'âge, 3, 4, et 5 ans, 50 épreuves, comprenant 5 épreuves par jour (total, 3000 épreuves) dans un labyrinthe à stylet destiné aux jeunes enfants où le vrai parcours et les culs-de-sac ont été visibles.

Avec les épreuves 5-50, paires contre impaires, la constance selon *r* Pearson a été +.618±S.E. .018 pour tout le groupe. L'aptitude, mesurée par les résultats du temps et des erreurs est devenue meilleure avec l'âge. On a trouvé des differences de sexe en faveur des garçons dans la première épreuve, lesquelles ont disparu comme l'apprentissage a continué. Le rapport entre l'intelligence, mesurée par les tests, et les résultats dans le labyrinthe a été léger. Les différences individuelles ont diminué avec l'exercice, mesurées par le gain total, le pourcentage du gain après la première épreuve, ou les coéfficients de variabilité. On a éliminé d'abord les erreurs dans les derniers culs-de-sac, ensuite celles des premiers.

La comparaison avec un test où l'on a employé des formes cachées d'un labyrinthe, a donné l'hypothèse que les différences d'aptitude dans les premières épreuves entre les enfants ont été dues à "l'aptitude à voir les formes," en partie indépendante de l'intelligence.

Le pourcentage des enfants qui ont commencé par la main droite est devenu plus grand avec l'âge, bien que la forme ait été telle que le stylet a été au côté gauche du labyrinthe. Les enfants plus âgés ont changé de main moins fréquemment pendant une seule épreuve. Dans tous les trois groupes les enfants faisant la plus grande vitesse ont tendu à se servir de la même main pendant toute l'épreuve.

La seconde partie du problème a consisté en deux expériences où des groupes d'enfants mis en paires ont appris quatre formes de la même difficulté d'un labyrinthe à stylet où les suggestions visuelles ont été semblables. Vingt-quatre enfants ont eu 3260 épreuves. Les groupes ont été mis en paires selon l'âge chronologique, l'âge mental, I. Q., le sexe, et l'aptitude montrée dans l'expérience antérieure du labyrinthe. Chaque enfant a eu 50 épreuves, cinq épreuves par jour. La constance pour les différentes formes a varié de +.3 à +.6.

Dans chaque groupe, sans égard de l'ordre où l'on a donné les formes, il y a eu un transfert défini d'une forme à l'autre, mesuré par le temps total, les erreurs, ou la différence dans les moyennes des cinq dernières épreuves d'une forme et les cinq premières épreuves de l'autre.

On a trouvé moins d'erreurs identiques les jours successifs de l'exercice que dans les épreuves successives, ce qui est semblable aux résultats obtenus par Lashley avec les rats.

Il n'y a pas eu d'élimination rétrograde des erreurs. On a éliminé les culs-de-sac le plus près du but, ensuite ceux du commencement, avant ceux du milieu.

McGINNIS

ÜBER DIE ACQUISTION UND INTERFERENZ DER MOTORISCHEN GEWOHNHEITEN KLEINER KINDER

(Referat)

Man gab 20 Kindern von 3 Altersstufen, i. e., 3, 4, und 5 jährig, 50 Tests, 5 per Tag (im ganzen 3,000 Tests) mit einem Stift Labyrinth besonders für kleine Kinder bestimmt, woran der richtige Pfad und die culs-de-sac sichtbar waren.

Bei Tests 5-50, gerade gegen ungerade, war die Zuverlässigkeit des Pearsonschen r .618±S.E. .018 für die ganze Gruppe. Fähigkeit, nach der Zeitdauer und Zahl der Fehler bemessen, nahm mit dem Alter zu. Geschlechtsunterschiede zu gunsten der Knaben, die man beim ersten Versuch vorfand, verschwanden bei zunehmender Geschicklichkeit. Die Beziehung zwischen Intelligenz, nach Tests bemessen, und den Leistungswerten mit dem Labyrinth war sehr gering. Individuelle Unterschiede nahmen durch Übung ab, ob sie nun durch den Totalgewinn, durch den Prozentsatzgewinn über den ersten Versuch oder durch Koeffizienten der Variabilität bemessen wurden. Fehler in den letzten culs-de-sac wurden zuerst ausgeschaltet, dann in jenen des Anfangs.

Ein Vergleich mit einem Versuch wobei versteckte Labyrinth Muster benutzt wurden, führte zu der Hypothese, dass Unterschiede in der Fähigkeit der Kinder beim ersten Versuch durch eine gewisse "Fähigkeit Muster zu sehen" bedingt werden, die zum Teil unabhängig von der Intelligenz ist.

Die Anzahl der Kinder die mit der rechten Hand anfingen nahm mit dem Alter zu, obgleich bei dem Muster der Stift an der linken Seite des Labyrinths war. "Ältere Kinder wechselten seltner von einer Hand zur andern bei einem einzelnen Versuch. In allen 3 Gruppen gebrauchten die Kinder, die am schnellsten arbeiteten, meistens dieselbe Hand während des ganzen Versuchs.

Der zweite Teil des Problems bestand aus 2 Experimenten, wobei Gruppen von Kindern paarweise 4 Muster in einem Stift Labyrinth von derselben Schwierigkeit und denselben sichtbaren Anhaltspunkten lernten. Man gab 24 Kindern, 3,260 Tests. Die Gruppen waren von demselben Alter, Geschlecht und Intelligenz Alter sowie von gleicher Intelligenz und Fähigkeit wie man durch frühere Experimente ermittelt hatte. Man gab jedem Kind 50 Tests, i. e., 5 täglich. Die Zuverlässigkeit der verschiedenen Muster variierte von +.3 bis +.6.

In jeder Gruppe, ganz abgesehen von der Reihenfolge in welcher die Muster gegeben wurden, fand sich eine entschiedene Übertragung von einem Muster zum nächsten, ob nach der Zeitdauer, der Fehlerzahl oder dem Unterschied der Mittel der letzten 5 Versuche eines Musters und der ersten 5 Versuche des folgenden Musters, bemessen.

Man fand seltener dieselben Fehler an aufeinander folgenden Tagen als bei aufeinander folgenden Versuchen, ähnlich der Resultate Lashleys mit Ratten.

Es gab keine rückwärtige Ausscheidung von Fehlern. Die letzten culs-de-sac wurden zuerst ausgeschieden, dann die ersten, und zuletzt die in der Mitte.

McGinnis

ПРИОБРЕТЕНИЕ И ВЗАИМООТНОШЕНИЕ МОТОРНЫХ НАВЫКОВ У МАЛЕНЬКИХ ДЕТЕЙ.

(Реферат)

По двадцати детей трех возрастов: 3, 4 и 5 лет были подвергнуты опыту со специальным графическим лабиринтом, рассчитанным на маленьких детей; в лабиринте как правильный путь, так и тупики были в поле зрения; с каждым ребенком было проведено 50 опытов. по пять каждый день (всего 3.000 опытов).

После обработки опытов с 5-го по 50-й, корреляция между четными и нечетными испытаниями по Пирсоновскому r была $+.618 \pm S.E.018$ — в отношении всей группы. Успешность, измеренная во времени и числе ошибок, поднималась с возрастом. В начальных попытках преимущество оказалось на стороне мальчиков; при продолжении процесса выучивания, оно пропадало. Связь интеллигентности, измеренной в тестах и успешности в решении лабиринта, была незначительна. Индивидуальные различия снижались с упражнением (одинаково, если измерять их в абсолютных величинах, или в процентном отношении к начальному опыту или коэффициентном вариативности). Ошибки в последних тупиках исчезали раньше, чем ошибки в первых тупиках.

Сравнение данных с тестом, в котором применялись специальные картинки-лабиринты; повело к гипотезе, что различия в успешности первых попыток у отдельных детей зависят от „формы рассматривания", которая частично независима от интеллекта.

Число детей, работавших правой рукой, поднималось с возрастом; обычно дети начинали решать лабиринт, держа карандаш в правой части рисунка. Старшие дети в единичных попытках менее часто переходили от работы одной рукой к работе другой. Во всех трех группах дети, достигавшие наиболее быстрого успеха, пользовались в течение всей попытки одной и той же рукой.

Вторая часть работ состоит из двух экспериментов, в которых парные группы детей обучались на четырех типах лабиринтов одинаковой трудности, в которых зрительные указатели были также одинаковые. С 24 детьми было поставлено 3.260 опытов. Группы эти располагались по паспортному, интеллектуальному возрасту, JQ, полу и успешности в решении прежних лабиринтов. С каждым ребенком было проведено 50 опытов, по пяти ежедневно. Надежность различных образцов колебалась от $+.3$ до $+.6$.

В каждой группе, независимо от порядка пред'явления задач, отмечался перенос от одной задачи к другой, изменяемый во времени, ошибках или в различии в отношении пяти последних попыток с одной задачей и пяти первых— с другой:

У этих испытуемых было найдено меньше идентичных ошибок в следующих после упражнения днях опытов, чем в последовательных попытках; эти результаты сходны с полученными в опытах Lashley с крысами.

Совсем не отмечалось ретроспективного устранения ошибок. Тупики, наиболее близкие к цели, и уже затем—самые близкие к началу, избегались раньше, чем расположенные в средине.

Мак Гиннис (McGinnis)

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